Radiological Health Data and Reports

VOLUME 8, NUMBER 7
July 1967
(Pages 355-414)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dĕk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mī' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.206 lb
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi per square meter (mCi/km^2)
MeV	million (mega) electron volts.	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi per square mile
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs per gram

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 8, Number 7, July 1967

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the National Center for Radiological Health by Federal agencies, State health departments, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
Department of Agriculture
Department of Commerce
Department of Health, Education, and Welfare
Atomic Energy Commission

CONTENTS

REPORTS

Page

Distribution of Strontium and Calcium in Major Vegetable and Fruit Crops and Criteria for Use of Fallout Contaminated Foods 355
J. W. Ralls, S. Primbsch, T. R. Guckeen, H. J. Maagdenberg, J. Rinehart, F. C. Lamb and W. A. Mercer

Aerial Measurement of the Kiwi Transient Nuclear Test 359
R. D. Coleman and V. E. Andrews

Summary of Population Exposure to X Rays in the United States, 1964 367
Population Studies Program, NCRH

DATA

SECTION I. MILK AND FOOD 375

National and International Milk Surveillance 376

1. Pasteurized Milk Network, March 1967, *PHS* 376
2. Canadian Milk Network, March 1967 379
3. Pan American Milk Sampling Program, March 1967, *PAHO* and *PHS* 380

State Milk Surveillance Activities 381

1. Colorado Milk Network, January–March 1967 381
2. Oklahoma Milk Network, January–March 1967 383
3. Tennessee Milk Network, January–March 1967 384
4. Texas Milk Network, January–March 1967 385

CONTENTS—continued

	Page
Food and Diet Surveillance Activities	387
1. Radionuclides in Institutional Diet Samples, October–December 1966, *PHS*	388
SECTION II. WATER	392
Gross Radioactivity in Surface Waters of the United States, January 1967, *FWPCA*	393
SECTION III. AIR AND DEPOSITION	395
Radioactivity in Airborne Particulates and Precipitation	395
1. Radiation Surveillance Network, March 1967	396
2. Canadian Air and Precipitation Monitoring Program, March 1967	399
3. Mexican Air Monitoring Program, March 1967	400
4. Pan American Air Sampling Program, March 1967, *PAHO* and *PHS*	401
SECTION IV. OTHER DATA	403
Strontium-90 in Human Bone, July–September 1966 *PHS*	403
Environmental Levels of Radioactivity at Atomic Energy Commission Installations	406
1. Paducah Plant, July–December and Calendar Year 1966	406
2. Pinellas Peninsula Plant, July–December 1966	409
3. Shippingport Atomic Power Station, July–December and Calendar Year 1966	410
SECTION V. TECHNICAL NOTES	413
Reported Nuclear Detonations, June 1967	413
Synopsis	iii
Symbols, Units, and Equivalents	Inside front cover
Guide for Authors	Inside back cover

RADIOLOGICAL HEALTH DATA AND REPORTS

Published under the direction of

James G. Terrill, Jr., Director and
Dr. Raymond T. Moore, Deputy Director
National Center for Radiological Health

by the Standards and Intelligence Branch
National Center for Radiological Health
Donald L. Snow, Chief

BOARD OF EDITORIAL ADVISORS

Dr. Hugh B. Mitchell
Department of Defense
Dr. Ronald G. Menzel
Department of Agriculture
Dr. Wilfrid B. Mann
Department of Commerce
Robert E. Simpson
Food & Drug Administration, DHEW
John A. Harris
Atomic Energy Commission

STAFF

Managing Editor
Samuel Wieder
Assistant Managing Editor
Charles F. Coyle
Senior Technical Editor
Marvin Rosenstein
Technical Editors
Kurt L. Feldmann
Richard Wromble
Illustrator
Marylee Hill

Address correspondence to the Managing Editor, *Radiological Health Data and Reports*, National Center for Radiological Health, Public Health Service, Rockville, Md. 20852.

For subscriptions to *Radiological Health Data and Reports*, please use the order form on last page of this issue.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service ● National Center for Radiological Health

Reports

Distribution of Strontium and Calcium in Major Vegetable and Fruit Crops and Criteria for Use of Fallout–Contaminated Foods

J. W. Ralls, S. Primbsch, T. R. Guckeen, H. J. Maagdenberg, J. Rinehart, F. C. Lamb, and W. A. Mercer [1]

Vegetable and fruit crops were grown in soil enriched with high levels of strontium nitrate. The normally edible portions of the crops were harvested and sectioned into anatomically distinct portions. The strontium and calcium content was measured by flame spectrophotometry or by photon activation analysis. The results are tabulated to provide an upper limit for radiostrontium content of crops grown in soil heavily contaminated with debris from nuclear fission on a massive scale.

If a massive release of radioactivity derived from the fission of heavy elements ever occurs, it may be necessary to attempt to decontaminate and to use some of the crops that had been exposed to airborne fallout. In subsequent years, the problem will be somewhat different; crops will also be contaminated with strontium–90 and other radionuclides absorbed from the soil through the root system. In order to minimize the ingestion of strontium–90 from such crops, it would be helpful to know the distribution of radiostrontium in specific parts of major food commodities.

This report deals with the problem of radiostrontium in foods grown in exposed soil where internal incorporation of strontium would occur. The study was made using experimental soil which was enriched with stable strontium at levels approaching the saline toxicity point. This experimental design was followed to insure crop samples with strontium levels which could be measured readily and accurately. The actual values obtained serve as an indication of the tendency of various fruits and vegetables to incorporate strontium when grown in soil contaminated at maximum levels. It should be emphasized that crops grown in soils containing micro levels of radioactive strontium would have different absolute and differential levels of radioactivity than those reported here.

For some vegetables and fruits, the maximum uptake of strontium from soil may be so low that the food would be safe for consumption, even from heavily contaminated soil. In other food items, a differential uptake of strontium into distinct parts of vegetables or fruits may render portions of the food safe after removal of the contaminated part.

Addition of the stable strontium in the form of the initially readily soluble nitrate makes its availability for root absorption greater than the predominant oxide and carbonate forms in fallout.

Materials and methods

Vegetable crops (broccoli, spinach, peas, corn, tomatoes, potatoes) were grown in a synthetic soil (UC Mix) *(1)* contained in drained 5-gallon pails. The top 4 inches of the soil contained added strontium nitrate at the rate of 2 grams per kilogram of soil. This level of enrichment represented 830 ppm of strontium in the upper layer of soil at the start of the crop growth period.

Dwarf fruit trees (apple, peach, pear and lemon) were grown in soil contained in large wood tubs. The top 6 inches of synthetic soil was enriched with 10 grams of strontium nitrate per kilogram of soil (4,150 ppm). The

[1] Research Foundation, National Canners Association, 1950–Sixth Street, Berkeley, Calif. 94710.

tubs containing the fruit trees were flushed three times with large volumes of water to reduce the salt level after signs of saline toxicity were noted. The level of strontium in the soil was measured after 14 months of tree growth and sporadic irrigation. The content of strontium in the soil (on a dry weight basis) at various levels (in 4-inch sections) is tabulated in table 1. The variability of strontium content of soils in different fruit tree containers is due to a nonuniform irrigation schedule for each individual soil container.

Table 1. Vertical distribution of strontium in soil of fruit tree containers [a]

Fruit tree container	Stable strontium content in various soil layers [b] (ppm/dry weight basis)			
	Top layer	Upper layer	Lower layer	Bottom layer
1	Not measured	2,980	2,970	2,720
2	1,240	1,350	1,960	4,710
3	1,100	1,090	1,250	2,080
4	1,460	2,760	2,070	1,350
5	741	1,920	2,460	1,990

[a] Measured after 14 months of tree growth and sporadic irrigation.
[b] Four-inch thick sections.

Crop samples were harvested at a time corresponding to the commercial maturity of each commodity. The edible portion of each crop was divided into its major distinct anatomical parts. Each portion was wrapped in plastic foil and stored frozen until analysis for strontium content. The crop samples were placed in tared platinum crucibles and heated in a muffle furnace at 600° C. After about 1 hour, large pieces of ash were broken up to insure complete and rapid ashing. The ashing was continued until a stable white material was obtained.

The ash sample in each crucible was slurried in water and transferred to a 100-ml beaker. Concentrated hydrochloric acid was added until the suspension had a pH of 1 to 2. After the addition of boiling chips, the contents of the beaker were heated and evaporated to a volume of about 20 ml. The suspension was filtered. The filtrate and rinsings were combined and made up to a volume of 50 ml with distilled water.

An aliquot equivalent to 20 grams of fresh sample was transferred to a 50-ml centrifuge tube. When necessary, the aliquot was evaporated to a volume of 10 ml in a boiling water bath. After the addition of four drops of bromothymol blue indicator, the solution was neutralized with 3 N NH_4OH. If necessary, the volume was adjusted to 10 ml with distilled water and 5 ml of 2 N hydrochloric acid added with mixing. The solution was heated to the boiling point and mixed with 10 ml of hot 3 N ammonium oxalate solution. The mixture was neutralized with 3 N ammonium hydroxide and the precipitate separated by centrifugation. The precipitation removed all strontium and calcium along with a small amount of magnesium. All of the barium remained in solution. The precipitate was dissolved in 1 ml of 2 N hydrochloric acid by careful heating over a flame. The solution was poured into a 5-ml porcelain crucible. The centrifuge tube was rinsed with three 0.5-ml portions of 2 N hydrochloric acid. The solution was evaporated to dryness under a heat lamp. The crucible was placed in a muffle furnace and heated to 750° to 800° C. until the oxalate salts were converted to the oxides.

Large sheets of Whatman No. 1 paper were cut to 10 by 7¾-inch size. A thin pencil line was drawn 1 to 1½ inches from one edge along the short dimension. The paper sheets were hung in a chromatography tank containing a 2:2:1 mixture of ethanol-methanol-2 N hydrochloric acid until the solvent ascended the length of the paper. The sheets were removed and thoroughly dried before the sample was applied.

The mixed oxide ash was dissolved in 0.5 ml of 2 N hydrochloric acid. The solution was drawn up into a streaking pipette (Microchemical Specialties, Berkeley, Calif., Model MLB) and applied along the origin line of the washed paper. Heat from a hair dryer was used to reduce drying time between applications. Two 0.2-ml portions of the 2 N hydrochloric acid were used to rinse the crucible and streaking pipette. The rinsings were applied to the paper by streaking the pipette contents along the origin line.

The dry papers were suspended from glass rods in a chromatography tank. The developing

solvent mixture was allowed to ascend to within ½ inch of the top of the paper during approximately 2 hours. The papers were removed immediately from the tank and dried.

The paper was hung in a spray chamber and sprayed with a 0.5 percent solution of 8-hydroxyquinoline in methanol-water (3:2) until evenly coated and nearly saturated. After about 10 seconds, the paper was sprayed lightly with concentrated ammonium hydroxide solution. The bands of magnesium, calcium, and strontium complexes were readily seen when viewed under ultraviolet light. While the paper was still damp, pencil lines were drawn between the boundaries of the separated cations.

The individual calcium and strontium bands were cut out of the dry paper and placed in 15 ml porcelain crucibles. The crucibles were put into a cold muffle furnace, the heat control set at the highest setting, and the furnace turned on. The temperature was allowed to increase about 750° to 800° C. and then the furnace was turned off.

The ash was dissolved in 5 ml of 0.5 N hydrochloric acid solution. Dilutions of this solution can be adjusted within the concentration ranges of the standard solutions.

The concentration of strontium and of calcium in the solution was measured by use of a Beckman DU Flame Spectrophotometer using a hydrogen-oxygen burner. A test of the precision and accuracy of the complete analytical procedure was made using standard solutions of calcium chloride and strontium nitrate. The recovery of calcium was 82.7 ± 4.0 percent, and the strontium was 99.5 ± 1.7 percent, both at the 100-ppm level.

Some samples were not available in a large enough quantity to be analyzed by the flame photometric method. The strontium content of these samples was determined by a method of activation analysis developed by the General Atomics Division, General Dynamics Corporation, San Diego, Calif. (*2*). Each sample and a standard were irradiated for 1 hour in a photon field produced by converting a 500 microampere beam of 25-MeV electrons to photons with a tungsten target. These energetic photons produced the radioactive strontium-87m (half-life 2.8 hours) via the strontium-88(γ,n) strontium-87m reaction. The 0.388-MeV gamma rays from the strontium-87m were measured, with a multichannel analyzer, as a function of the strontium–88 originally present in the sample. The results from the determination of calcium and strontium are tabulated in table 2. The values are averages of triplicate determinations on at least six samples from different soil containers.

Discussion

A number of important conclusions can be drawn from the data in table 2. If soils should become heavily contaminated with radioactive fallout, one would expect that the accumulation of radiostrontium in various commodities would be as shown below:

Accumulate least radiostrontium—corn, apple, peach, pear;

Accumulate intermediate amounts of radiostrontium—broccoli, potato;

Accumulate most radiostrontium — lemon, peas, spinach, tomato.

Inspection of table 2 will also provide information for the selection of crops for potential decontamination by modified processing. The high strontium content and the physical nature of the material would make spinach, broccoli, and peas unlikely candidates for decontamination. In fact, it would be unwise to grow these crops until the land to be used had been demonstrated to be free of radioactive strontium.

Lemon and tomato juices could be decontaminated by an ion exchange process. This operation warrants serious consideration due to the important nutritional role these commodities play.

The work of Perkins and Strachon (*3*) on the removal of cesium–137 from potatoes suggests that a similar treatment would reduce strontium–90 contamination. Dubrovina and Belova (*4*) have reported that simple boiling in water will remove 20 percent of the initial strontium content of contaminated potatoes.

The ratio of strontium to calcium in the major edible portion of the commodities tabulated in table 2 is not constant. Therefore, it is not possible to estimate strontium content from the known calcium content of these fruits and vegetables.

Table 2. Strontium and calcium content of vegetable and fruit parts from samples grown in strontium enriched soil and in control soil

Commodity	Strontium content [a,b] (ppm)		Calcium content [a,b] (ppm)		Sr/ca ratio for enriched soil
	Control soil	Enriched soil	Control soil	Enriched soil	
Potato:					
Pulp	0.75	7.8	164	192	.041
Peel	< .5	4.6	130	130	.035
Broccoli:					
Buds	.4	7.5	1,380	589	.013
Stalk	.4	4.5	206	240	.019
Leaf	.1	6.4	2,130	1,010	.006
Leaf vein	< .5	6.3	877	1,290	.005
Spinach:					
Leaf	2.6	10.1	634	663	.015
Vein	1.8	4.4	181	171	.026
Stem	1.7	1.0	109	63	.016
Peas:					
Seed	< .5	42.7	311	561	.076
Pod	3.7	186	1,817	1,584	.118
Seed embryo	642	4,000	[c]	[c]	
Corn:					
Skin	< .5	< .5	249	83	
Milk	< .5	< .5	11	83	
Pulp	< .5	< .5	12	70	
Tomato:					
Juice	< .5	9.7	54	86	.113
Skin	.5	42	150	240	.175
Pears:					
Flesh	< .5	1.6	14	45	.036
Peel	< .5	10.5	65	270	.039
Core	< .5	5.1	125	51	.100
Seed	[c]	34	[c]	[c]	
Apples:					
Flesh	[c]	.5	[c]	7.5	.067
Peel	[c]	12.2	[c]	79	.154
Core	[c]	25.5	[c]	103	.248
Peaches:					
Flesh	[c]	0.74	[c]	55	.013
Peel	[c]	2.9	[c]	319	.009
Pit	[c]	1.8	[c]	229	.008
Lemon:					
Juice	[c]	57	[c]	[c]	
Pulp	[c]	521	[c]	[c]	
Peel	[c]	563	[c]	[c]	

[a] Fresh weight basis.

[b] Assuming that all the strontium is strontium-90, the equivalent hypothetical radioactivity can be calculated from the expression:

$$\text{pCi strontium-90/g calcium} = 1.42 \times 10^{11} \left(\frac{\text{ppm strontium}}{\text{ppm calcium}} \right)$$

[c] Not measured.

Acknowledgments

The work reported here was done, in part, under Research and Service Contract 12–14–100–7187(74) with the Agricultural Research Service, U.S. Department of Agriculture. Reference to a company or product names does not imply approval or recommendation of the product by the U.S. Department of Agriculture, the Public Health Service, or the U.S. Department of Health, Education, and Welfare, and does not imply that there are no other suitable products available commercially.

REFERENCES

(*1*) BAKER, K. F., Editor. The U.C. System for Producing Healthy Container-Grown Plants. University of California. Division of Agricultural Sciences, Berkeley, Calif. (1957).

(*2*) ANDERSON, G. H. Private communication, November 22, 1965.

(*3*) PERKINS, H. J., and G. STRACHON. Science 144(3614), 59–60 (1964).

(*4*) DUBROVINA, Z. V., and O. M. BELOVA. Gigiena i Sanit 29(2):40–43 (1964); Chem Absts 60:15045h (1964).

Aerial Measurement of the Kiwi Transient Nuclear Test[1]

R. D. Coleman and V. E. Andrews[2]

The Los Alamos Scientific Laboratory conducted a Transient Nuclear Test on a KIWI Reactor on January 12, 1965, at the Nuclear Rocket Development Station at Jackass Flats, Nev. During this planned destructive test of a propulsion reactor, the Public Health Service's Southwestern Radiological Health Laboratory conducted a land and aerial offsite radiological surveillance program. The aerial aspects of the laboratory's program included sampling and assay missions along flight patterns through the radioactive cloud formed by the destruction of the reactor. Samples obtained from these aerial missions were analyzed to define various characteristics of the cloud. The aircraft made repeated measurements of peak gamma levels in the cloud. The decrease of peak gamma-ray readings with distance from the site of the experiment was exceptionally rapid. The reduction is attributed to a combination of decay and excellent meteorological diffusion.

To advance technology on conditions during and following a nuclear excursion, a nuclear reactor was purposefully destroyed in Nevada on January 12, 1965 and the power excursion was carefully monitored and documented. This was the first such planned destructive test of a propulsion reactor. It was labeled the Transient Nuclear Test of the Kiwi B4E reactor and was a part of the Rover Flight Safety Program. The test was a joint Atomic Energy Commission-(AEC)-National Aeronautics and Space Administration (NASA) project conducted by the Los Alamos Scientific Laboratory at the NASA Nuclear Rocket Development Station, Jackass Flats, Nev., at 1058 hours (defined herein as "H-hour"). The time of excursion was 2.1 milliseconds on a period of 0.63 milliseconds. The excursion resulted in 3×10^{20} fissions and the peak thermal power was 3.3×10^{6} megawatts.

Data from the excursion will be used to obtain basic reactor shutdown information which can be used to predict theoretically the dynamic behavior of nuclear rocket reactors under a wide range of accident conditions. One major test objective was to determine the release and subsequent movement of effluent from the reactor (*1*).

In conjunction with the planned excursion, the Public Health Service's Southwestern Radiological Health Laboratory conducted surface and aerial radiation surveillance. Two cloud measuring and sampling aircraft were utilized by the Public Health Service to document the aerial release downwind from the reactor.

This report describes the aerial measurement procedures used by the Public Health Service during the surveillance of the Kiwi Transient Nuclear Test. Also presented are the results of particle size determinations and laboratory measurements of the type and amounts of radioactivity in the release.

Equipment

The two aircraft used by the Southwestern Radiological Health Laboratory to monitor the test were Twin Beechcraft, relicensed C-45's obtained from Air Force surplus. Each was equipped with gamma-ray detection devices. One plane was used to measure the height of rise of the atmospheric release and was identified as the cloud-height aircraft. The second plane was equipped to determine the projected area and position of the release and take representative samples of the release composition and

[1] Presented orally at the Tenth Annual Meeting of the Health Physics Society, June 14–17, 1965, Statler-Hilton Hotel, Los Angeles, Calif.

[2] Chief and assistant chief, Engineering Development Program, Southwestern Radiological Health Laboratory, DHEW, Las Vegas, Nev.

characteristics. This aircraft was designated as the sampling plane. Three sampling systems were used in the sampling plane. They were an electrostatic precipitator system, a cryogenic sampling system, and a Casella cascade impactor fitted with an isokinetic intake probe.

The electrostatic precipitator was a 3-foot long, 2.8-inch inside diameter tube with an axially mounted wire insulated from the tube. An 18,000 volt potential was maintained between the wire and the tube; the tube was positive with respect to the wire. An 8- by 10-inch, 0.45μ pore-size membrane filter, reinforced with nylon webbing, was placed at the end of the tube to trap any particulates not collected on the tube. Two Bureau of Mines 2306 activated-charcoal cartridges were placed in series behind the filter to collect any reactive gases, mainly iodine. Air was drawn through the assembly by a centrifugal blower. A grab sample of the blower exhaust air was collected in a plastic bag during the peak level of radioactivity and was compressed into an evacuated gas cylinder. The sample flow rate was about 8.6 cfm. In the laboratory, the collected particulate radioactivity was removed by washing the tube with isopropyl alcohol and filtering through a 47-mm diameter, 0.45μ pore-size membrane filter.

In the cryogenic sampling system, the air passed through a 2-inch diameter membrane filter, reinforced with nylon webbing, and through a Bureau of Mines 2306 charcoal cartridge before entering the cryogenic portion. The cryogenic sampler consisted of a series of traps submerged in liquid nitrogen, kept at 10 to 15 psi gage. At this pressure, the boiling point of nitrogen is 82° K or −191° C. The air passed successively through a water trap, a snow trap, and a sampling portion filled with 5A molecular sieve, which collected the inert gases. Air was drawn through the system by a double diaphragm pump and the pump discharged through a dry-gas meter. The initial flow rate was 4 cfm and the average flow rate for the total sample was 3 cfm.

The cascade impactor unit used during the surveillance was the commercially available Casella unit fitted with an isokinetic intake probe.

The gamma-ray detection equipment on the sampling plane consisted of a 3- by 3-inch sodium iodide crystal connected to a portable, single-channel pulse height analyzer using a window of 0 to 2 MeV. The gross gamma-ray output from the analyzer was recorded on a strip chart. Gamma-ray dose rate measurements were made with a high range, portable ionization chamber instrument with a range of 0.05 to 50,000 mR/hr on two logarithmic scales.

The cloud-height plane was equipped with a low-range scintillator monitoring instrument having a range of 0 to 5 mR/hr in six scales for gamma-ray detection and measurement. Output from the scintillator was recorded on a strip chart. An external probe with a filter inside the cabin for particle collection was utilized to confirm cloud presence. Impact pressure on the intake moved air through the filter. In addition, two experimental cloud detection systems were carried in the plane for performance evaluation.

Monitoring methods

On the basis of information received from Air Force cloud tracking aircraft which made early penetrations, a flight path was established ahead of the cloud mass and normal to the projected trajectory of the cloud. This intercept was selected so that a known geographical check point was available on either side, but outside the path of the cloud.

The sampling plane flew the interception pattern at 6,000-feet Mean Sea Level (MSL). To continually reference the release cloud relative to the ground, the strip chart of the gamma-ray detector was marked each time the aircraft was over a check point.

The cloud height plane flew at 500-foot increments in altitude above the sample plane, collecting separate filters at each discrete altitude. These samples were analyzed for gross beta radioactivity and identified as either positive or negative and the height of rise of the release was established as halfway between the altitudes for positive and negative results.

The speed of the cloud was calculated from the time required for the radioactivity to travel from the release point to the intercept path. The distance that the cloud traveled between passes was calculated from the time between

midpoint of the passes and the cloud speed. Cross-sectional area was calculated for each pass using the measured width and height and assuming an elliptical shape as viewed axially. Cloud volume was then determined by the average-end areas method (*2*). This method is normally used in determining earth volumes in cut and fill operations in construction. An average cross-section area is determined for each segment of the cloud between two passes by averaging the cross-section areas at the two passes. The volume for that segment is the product of the average cross-section area and the distance of cloud travel between the two passes.

Monitoring results

The aircraft passed through the cloud eleven times along the established path. In the plan view of the cloud (figure 1), the observed width and location of the cloud on each pass were progressively displaced forward and back from the flight path along the cloud axis to show the appearance of the cloud as it passed the flight line on each pass. In figure 1, the cloud is normalized at 1220 hours on the flight path. The cloud required 1 hour and 10 minutes to pass the intercept and, by the treatment described, was 22-miles long. The observed maximum width was 8.4 miles on pass 8 at 1230 hours. The top of the cloud was at 10,500-feet MSL in an area where terrain was 2,500-feet MSL. Positive ground level samples on Highway 95 west of Lathrop Wells documented the presence of the released material at ground level and verified the full 8,000-feet cloud height. Using the "average-end areas" method, the volume which passed the flight path was determined to be 2.4×10^{13} ambient cubic feet.

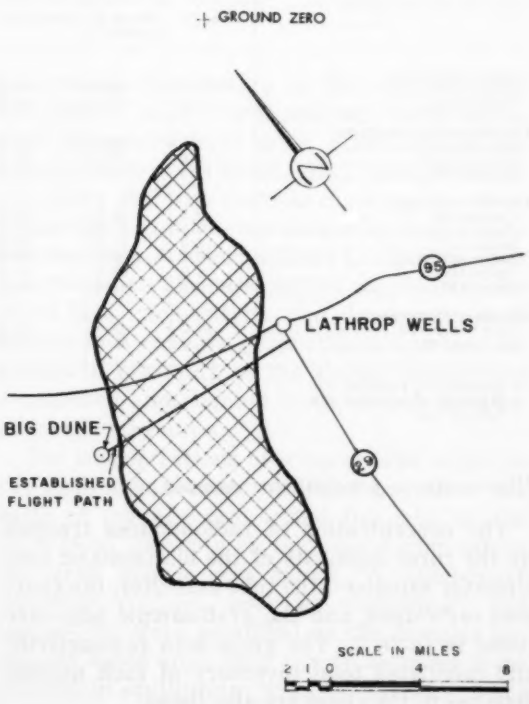

Figure 1. Progressive cross-sectional view of the Kiwi TNT cloud, normalized at 1220 hours along the flight line

Figure 2 shows the maximum exposure observed during each pass versus the time of observation as the cloud passed the flight line. Also indicated are the periods of sampling. The electrostatic precipitator operated during the entire cloud passage. A grab sample was collected during the peak reading of 14 mR/hr at 1207 hours. The cryogenic sampler was stopped after the seventh pass due to nitrogen depletion.

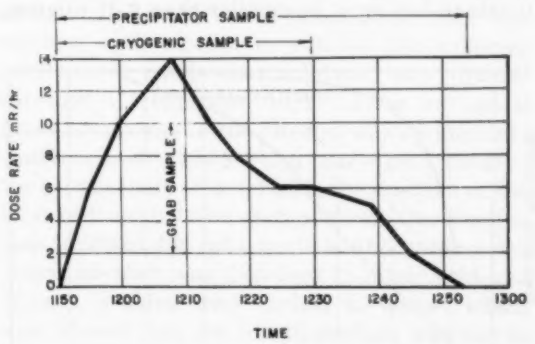

Figure 2. Maximum intensity of gamma-ray activity recorded during successive passes through the Kiwi TNT cloud versus time of reading of maximum intensity

Two other aircraft reported maximum dose rates of 50 R/hr at H + 5 minutes and 100 mR/hr at H + 35 minutes. These readings, with the 14 mR/hr reading at H + 70 minutes, indicate a decrease in dose rate with time (T) by a factor of $T^{-3.2}$.

Particle sizing

A cascade impactor was used to estimate the size range of the airborne particles. Pump limitations made it necessary to use a glass-fiber filter in the fifth stage to obtain design air flow and optical sizing of that stage was not possible; although a flow adjustment error set the flow at 35 liters per minute and optical sizing of the particles on all impaction stages became necessary.

Optical sizing revealed that stages two, three, and four, contained nearly identical particle size distributions; therefore, the data from these three stages were combined for interpretation. In figure 3, the curve representing the cumulative distribution of particles in stages two, three, and four is well separated from the curve representing stage one. In stage one, 73 percent of the particles were larger than 1 micron. In stages two, three, and four, 87 percent of the particles were less than 1 micron. With the system used, the smallest particle that could be sized was 0.47 micron. From the results of stages two, three, and four, it was determined that most, if not all, of the particles on stage five must be smaller than 0.47 micron.

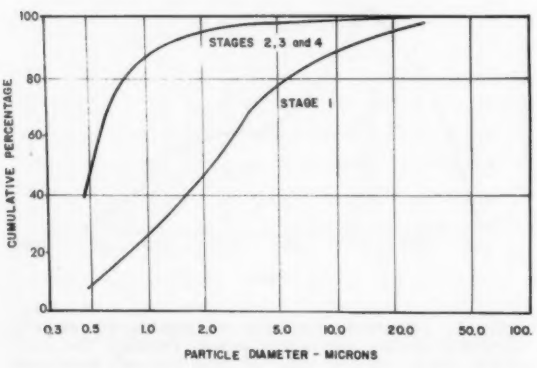

Figure 3. Distribution of particle sizes collected by four stages of a cascade impactor during passes through the Kiwi TNT cloud

The particulates collected on all five stages of the cascade impactor were counted for beta radioactivity and were analyzed by gamma-ray spectroscopy. The radionuclides identified on the five stages were grouped in table 1 according to whether the main precursor was a gaseous, gaseous plus volatile, volatile, or refractory element. The classification of volatile and refractory was made on the basis of boiling points relative to the actual temperature during the reactor excursion.

In table 1, barium, with its xenon precursors, is associated with the smaller particles. Generally, the next two groups, volatile and volatile-gaseous precursors, are associated with particles 0.5 to 2 microns in diameter; the exceptions are the iodines–133, –134, and –135 which are produced during fission and are primarily gaseous products associated with particles <1 micron in diameter. The radionuclides which are refractory or have refractory precursors are associated with the large particles.

Table 1. Percent distribution of radionuclides collected in the cascade impactor during passes through the Transient Nuclear Test cloud

Fission product	Percent activity		
	Stage 1 [a]	Stages 2, 3, and 4 [b]	Stage 5 [c]
Gaseous precursors:			
Barium-139	4.0	50.0	46.0
Barium-140	3.0	56.0	41.0
Volatile-gaseous precursors:			
Strontium-91	7.0	63.0	30.0
Strontium-92	5.0	70.0	25.0
Yttrium-92	11.0	74.0	15.0
Volatile precursors:			
Cerium-143	12.0	59.0	29.0
Tellurium-132	3.0	70.0	27.0
Iodine-131	17.0	57.0	26.0
Iodine-133	6.0	53.0	41.0
Iodine-134	2.0	51.0	47.0
Iodine-135	2.0	41.0	57.0
Refractory precursors:			
Molybdenum-99	40.0	49.0	11.0
Zirconium-97	34.0	53.0	13.0

[a] 73 percent of particles >1μ.
[b] 85 percent of particles <1μ.
[c] 0.47μ or less.

Electrostatic precipitator sample

The concentration of radionuclides trapped by the three segments of the electrostatic precipitator sampler—the tube and filter, the charcoal cartridges, and the grab-sample bag—are listed in table 2. The gross beta radioactivity and calculated total inventory of each nuclide detected in the cloud are also listed.

The gamma-emitting nuclides collected by the system were identified and quantitated by

Table 2. Concentrations of radionuclides collected on the three parts of electrostatic precipitator from the Transient Nuclear Test cloud

Isotope	Concentration (pCi/scf)			Total curies
	Electrostatic precipitator parts			
	Particulate	Charcoal	Grab	
Krypton-85m			280	5.4×10^{3}
Krypton-87			760	1.4×10^{4}
Krypton-88			1,200	2.3×10^{4}
Strontium-89	1.7			33
Strontium-90	0.19			0.4
Strontium-91	680			1.3×10^{4}
Strontium-92	2,950			5.6×10^{4}
Zirconium-niobium-95	12			2.3×10^{2}
Zirconium-97	1,480			2.8×10^{4}
Molybdenum-99	360			6.9×10^{3}
Ruthenium-103	8.2			1.6×10^{2}
Tellurium-132	80			1.5×10^{3}
Iodine-131	25	3.0		5.4×10^{3}
Iodine-133	325	7.3		6.3×10^{3}
Iodine-134	1,190	280		2.8×10^{4}
Iodine-135	535	89		1.2×10^{4}
Xenon-135		1.2	80	1.1×10^{3}
Cesium-138	3,560			6.8×10^{4}
Barium-139	214	4.8		4.2×10^{3}
Barium-140	11			2.1×10^{3}
Cerium-141	7.2			1.4×10^{3}
Cerium-143	310			5.9×10^{3}
Neodymium-147	11			2.1×10^{3}
Neptunium-239	7.0			1.3×10^{5}
Uranium-234	0.48			9.1
Gross beta radioactivity	8.1×10^{4}			1.58×10^{6}

gamma-ray spectroscopy on 200 channels of a 400-channel pulse height analyzer, using photopeak energy and decay rates. Strontium–89 and strontium–90 were quantitated through radiochemistry and beta-particle counting in a low-background, end-window Geiger counter. Uranium was separated and counted by alpha-particle spectroscopy. The backup filter was counted for gross beta radioactivity and decay rate on a 6- by 9-inch gas-flow proportional counter. An aliquot of one-ninth of the alcohol filtrate was evaporated and counted in the 2-inch internal proportional counter.

The concentrations of krypton and xenon in the grab sample were weighted by use of the ratio of average peak cloud intensity to the peak cloud intensity on the pass during which the grab sample was taken. A number of daughter nuclides, such as niobium–97 and iodine–132, were identified on the samples but are not listed since they can be assumed to be present in equilibrium with the parents. Some nuclides, such as the iodines, were collected, at least in part, as the precursors. However, since the precursors could not be quantitated, the activities of the nuclides were calculated as of the midpoint of the collection period.

The particulate gross beta radioactivity collected from the cloud averaged 81,000 pCi/standard cubic foot (scf) [3] at the midtime of collection. Using the volume of the cloud previously determined (2.4×10^{13} ambient cubic feet), an extrapolated total of 1.53×10^{6} curies were present in the cloud at 1220 hours. Addition of the gaseous isotopes collected on the charcoal and in the grab sample raised the cloud total to 1.58×10^{6} curies.

Most of the gross beta particulate radioactivity decayed at the rate of $T^{-1.69}$. The two exceptions were the activities collected by the backup 8- by 10-inch membrane filter, which followed the precipitator tube and contained 3 percent of the particulate radioactivity, and the alcohol soluble particulates from the precipitator tube which contained 2 percent of the particulate gross beta radioactivity; both decayed at the rate of $T^{-1.13}$.

The solubilities of the radionuclides collected on the electrostatic precipitator were investigated using isopropyl alcohol, 8N nitric acid, and distilled water. The precipitator tube was washed with alcohol to remove the collected particulates and the solution was passed through a membrane filter. After an initial gross beta count on the filter, it was divided into quarters and each portion was again counted for beta activity to determine the fraction of the total radioactivity on each portion. One portion was followed for beta particle and gamma-ray decay, another was dissolved in nitric acid and filtered, a third was washed in water, which was filtered, and the fourth portion was lost in process. From the results of gamma-ray spectroscopy on the fractions, it was possible to determine the percentage of each nuclide which was not soluble in each of the three agents—alcohol, water, and nitric acid. These results are given in table 3. Although other forms of these nuclides were not excluded by these solubility tests, the respective behaviors were consistent with behavior predicted for elemental or oxide forms of the isotopes reported. The

[3] Standard conditions used were 0°C. and 760-mm Hg.

results for iodine–131 indicate that it was collected and separated mainly as the tellurium precursor.

Table 3. Solubilities of radionuclides collected in the electrostatic precipitator from the Transient Nuclear Test cloud

Isotope	Percent insoluble		
	Alcohol	H_2O	8N HNO_3
Strontium-91, -92	85	75	75
Zirconium-95, -97	100	100	75
Molybdenum-99	100	100	95
Tellurium-132	95	100	70
Iodine-131	100	100	50
Iodine-133	80	90	60
Iodine-135	30	75	100
Cerium-141	95	100	100
Cerium-143	100	100	80

Cryogenic sampler

The type and quantity of nuclides collected on the three parts of the cryogenic sampler (the filter, charcoal cartridge, and cold trap) plus the calculated total quantity of each nuclide in the cloud at the midpoint of collection are presented in table 4. All values were adjusted, using the ratio of the average of the peak dose rates on each pass through the cloud during operation of the cryogenic sampler to the average of the peak dose rates on each pass through the cloud during cloud passage, to obtain the average concentration and quantity of nuclides in the cloud.

Beta-particle and gamma-ray analyses were performed on the prefilter, and gamma-ray analysis was made of the charcoal cartridge as in the case of the electrostatic precipitator. Gases were removed from the cold trap and separated using carrier gases on a specially designed system which combines the features of gas chromatography and low-temperature distillation. The resultant gases, which had been separated by element were counted for beta radioactivity in thin-walled, gas envelope Geiger tubes. Isotopic abundances were determined by counting a portion of the gas in glass flasks on a 400-channel pulse height analyzer.

As reflected in table 4, an unusually large portion of the radioactivity was collected on the charcoal cartridge. The anomaly was due to a hole that had developed in the filter during sampling but which was not discovered until the cryogenic sampler intake probe was dismantled after sampling.

Table 4. Concentrations of radionuclides collected in the cryogenic sampler from the Transient Nuclear Test cloud

Isotope	Concentration (pCi/scf)			Total curies
	Cryogenic sampler parts			
	Filter	Charcoal	Trap	
Krypton-85m	.....	.....	290	5.6×10^{3}
Krypton-87	.....	.....	780	1.5×10^{4}
Krypton-88	.....	.....	1,200	2.3×10^{4}
Strontium-91	200	48	.....	3.3×10^{3}
Strontium-92	520	130	.....	1.3×10^{4}
Zirconium-niobium-95	1.7	1.0	.....	52
Zirconium-97	210	190	.....	7.6×10^{3}
Molybdenum-99	75	67	.....	2.7×10^{3}
Ruthenium-103	1.3	1.5	.....	53
Tellurium-132	47	4.2	.....	9.4×10^{3}
Iodine-131	5.8	1.9	.....	1.5×10^{3}
Iodine-133	230	42	.....	5.2×10^{3}
Iodine-134	890	86	.....	1.9×10^{4}
Iodine-135	86	71	.....	3.0×10^{3}
Xenon-135	.....	47	67	2.2×10^{3}
Barium-139	1,200	38	.....	2.3×10^{4}
Barium-140	10	.....	.....	2.0×10^{3}
Cerium-141	0.94	.....	.....	18
Cerium-143	64	.....	.....	1.3×10^{3}
Neodymium-147	0.78	.....	.....	15
Gross beta radioactivity	1.2×10^{4}	.....	.....	2.8×10^{5}

The gross beta-particle concentration as determined from the filter was 1.2×10^4 pCi/scf. Adding the nuclides on the charcoal cartridge and cold trap, the total radioactivity detected in the cloud was 2.8×10^5 curies at 1220 hours. The gross beta radioactivity on the filter decayed at the rate of $T^{-1.08}$.

Discussion

Table 5 compares the total quantity of each nuclide detected by two sampling systems—the electrostatic precipitator and the cryogenic sampler—with the total quantity expected at H + 1.12 hours (1210 hours) from 3×10^{20} fissions, using the tables of Bolles and Ballou (*3*).

A comparison of the results of the cryogenic sampling system with those of the precipitator system indicated that, in general, the concentrations of individual nuclides and the total radioactivity levels in the cloud detected by the cryogenic system were about one-fourth those detected by the precipitator. Conversely, for 12 of 20 nuclides (table 5) the precipitator collected approximately 4 times more radioactivity per unit of sample than the cryogenic system.

Table 5. Comparison of the total quantities of radionuclides as determined from the precipitator and the cryogenic sampling system versus total amount expected from 3 x 10^{20} fissions at collection time

Isotope	Precipitator (curies)	Cryogenic (curies)	Expected (curies)
Krypton-85m	5.7×10^{3}	5.6×10^{3}	3.2×10^{3}
Krypton-87	1.4×10^{4}	1.5×10^{4}	1.8×10^{4}
Krypton-88	2.3×10^{4}	2.3×10^{4}	1.6×10^{4}
Strontium-89	33	----	47
Strontium-90	0.4	----	0.46
Strontium-91	1.3×10^{4}	3.3×10^{3}	7.9×10^{3}
Strontium-92	5.6×10^{4}	1.3×10^{4}	2.4×10^{4}
Zirconium-niobium-95	2.3×10^{3}	52	[a] 61
Zirconium-97	2.8×10^{4}	7.6×10^{3}	5.4×10^{3}
Molybdenum-99	6.9×10^{3}	2.7×10^{3}	1.3×10^{3}
Ruthenium-103	1.6×10^{3}	53	56
Tellurium-132	1.5×10^{3}	9.4×10^{2}	7.8×10^{3}
Iodine-131	5.4×10^{3}	1.5×10^{3}	[a] 1.3×10^{3}
Iodine-133	6.3×10^{3}	5.2×10^{3}	[a] 2.7×10^{3}
Iodine-134	2.8×10^{4}	1.9×10^{4}	5.2×10^{4}
Iodine-135	1.2×10^{4}	3.0×10^{3}	1.2×10^{4}
Xenon-135	1.1×10^{3}	2.2×10^{3}	1.4×10^{3}
Cesium-138	6.8×10^{4}	----	6.4×10^{4}
Barium-139	[b] 4.2×10^{3}	2.3×10^{4}	4.5×10^{4}
Barium-140	2.1×10^{3}	2.0×10^{3}	3.1×10^{3}
Cerium-141	1.4×10^{3}	18	[a] 15
Cerium-143	5.9×10^{3}	1.3×10^{3}	2.4×10^{3}
Neodymium-147	2.1×10^{3}	15	1.6×10^{3}
Neptunium-239	1.3×10^{3}	----	----
Uranium-234	9.1	----	----

[a] These values were extrapolated from the amount predicated for the time of count because they had not reached their maximum activity at the time of collection.
[b] This value for barium-139 too low, see text.

Exceptions were the kryptons, tellurium–132, iodine–133 and –134, xenon–135, and barium–140 which were about equal and barium–139 which was much higher for the cryogenic sampler.

Although it would seem that barium–139 must have been collected on the precipitator tube, it could not be identified on samples from that portion, but was found on the backup filter and charcoal. The difference in the values for neodymium–147 and cerium–141 is most likely due to poor counting statistics at the high background end of the gamma-ray spectrum.

The most likely explanation for the differences between the isotopic and gross beta-particle results obtained from the two sampling systems was the hole discovered in the cryogenic prefilter. Since the charcoal cartridge could not efficiently collect particulates, these passed on to the cryogenic trap, which was not analyzed for radioactivity other than for those gases which could be removed from the molecular sieve. This would be consistent with the observed close agreement of the radioactivity levels of the kryptons (table 5). The iodine–135 collected on the molecular sieve would also have approximately doubled the xenon–135 present during the time between collection and analysis; this would account for the larger quantity of xenon–135 detected on the cryogenic sampler.

On the basis of these interpretations, the most reliable figures for the quantities of nuclides except for barium–139, were those obtained from the electrostatic precipitator system.

A portion of the fuel cladding contained niobium which produced zirconium–97 by neutron activation. This produced a higher value for zirconium–97 than that expected from fission alone. Excluding this isotope and cerium–141, the inventories, as determined from the electrostatic precipitator system, for thirteen isotopes averaged 2.2 times the total expected. At least two possibilities could cause this: (1) a nonrepresentative sample or (2) an error in cloud volume.

As it is impossible to determine the degree to which the sample is representative, sources of error in cloud volume measurement were investigated. Cloud width and thickness were direct measurements and any errors therein should be relatively small. This left the cloud length as the major possible source of error.

Investigation of wind speeds in the area at every 1,000 feet in altitude showed that during the sampling period winds from ground level to the sampling altitude decreased to nearly one-half their speed at the start of the sampling period. This would indicate that the calculated cloud volume was approximately twice as large as it should have been and that the inventories shown are twice the actual values.

The quantity of cerium–141 is still far higher than would be expected. It is possible that this and portions of the other longer-lived isotopes were in the reactor core from previous low-level operations.

Under normal surveillance conditions, an error of a factor of two in the total inventory would be acceptable. However, on the basis of these results, flight operations have been modified to provide confirmation of cloud speed and length during sampling.

Summary

Immediately after the Kiwi Transient Nuclear Test occurred in Nevada on January 12, 1965, two specially equipped aircraft from the PHS Southwestern Radiological Health Laboratory made eleven passes through the effluent from the reactor. Using the on-board sampling equipment, 25 radionuclides were detected: krypton–85m, –87, and –88; strontium–89, –90, –91, and –92; zirconium-niobium–95; zirconium–97; molybdenum–99; ruthenium–103; tellurium–132; iodine–131, –133, –134, and –135; xenon–135; cesium–138; barium–139 and –140; cerium–141 and –143; neodymium–147; neptunium–239; and uranium–234. These nuclides were collected by the use of two different sampling systems—an electrostatic precipitator system and a cryogenic sampler. A third system, a cascade impactor, was used to determine the range and quantity of particle sizes in the cloud. The three systems were used because each one had a preferential efficiency for collecting and trapping different components of the cloud.

After interpreting the data and analyzing the systems, it was determined that the most reliable data on the quantities of nuclides in the cloud were those obtained from the electrostatic precipitator systems. One reason was that the cryogenic system prefilter partially ruptured during sampling. The amounts of radioactivity calculated from the results of the precipitator sampling system ranged from 0.4 curies of strontium–90 to 6.8×10^4 curies of cesium–138. It was determined that the volume of the cloud was 2.4×10^{13} cubic feet and that the total amount of gross beta radioactivity in the cloud was 1.6×10^6 curies; although, due to a change in wind speeds these values may be a factor of 2 too large.

The particle sizes detected in the cloud by the cascade impactor ranged from less than 0.5 to 30 microns. Combining the two "stage" categories of the cascade impactor, the percent distribution of the various particle sizes which could be optically sized was: 28 percent of the particles were less than 0.5μ in diameter; 30 percent were 0.5 to 1μ; and 12 percent were 5 to 30μ. Therefore, most of the particles which could be optically sized ranged in size from 0.5 to 5 microns.

Conclusions

The equipment and techniques presented made it possible to collect data and samples which were used to delineate the radioactive release from the Kiwi Transient Nuclear Test and to quantitate the gross and isotopic radioactivity in the release. With the exception of the error due to the change in wind speed the method of using a single flight path, repeatedly flown during cloud passage, offers a relatively efficient method for labeling and tracking aerial masses. This error is being reduced by new techniques to determine cloud speed during sampling.

REFERENCES

(*1*) U.S. ATOMIC ENERGY COMMISSION. "Kiwi-TNT" reactor safety test set at rocket station in Nevada. Joint AEC-NASA announcement H–1, U.S. Atomic Energy Commission, Washington, D.C., and Space Nuclear Propulsion Office, Jackass Flats, Nev. (January 4, 1965), p. 3.

(*2*) RAYNER, W. H. and M. O. SCHMIDT. Elementary surveying, 3rd Edition (1955), p. 163.

(*3*) BOLLES, R. C. and N. E. BALLOU. Calculated activities of U^{235} fission products. Research and Development Rep USNRDL 456; NS081–001 (August 30, 1956).

Summary of Population Exposure to X Rays in the United States, 1964

Population Studies Program [1]
National Center for Radiological Health

A summary of the highlights of *Population Exposure to X-Rays, U.S., 1964. A Report on the Public Health Service X-Ray Exposure Study*, Public Health Service Publication No. 1519 is presented. It is estimated that 58 percent of the 187 million civilian noninstitutional population of the United States had one or more X-ray visits. The estimated annual dental X-ray rate declined from 27.4 per 100 persons in 1961 to 26.8 in 1964. The estimated annual rate of medical X-ray visits increased from 47.9 per 100 persons in 1961 to 49.8 in 1964. Of the 173 million X-ray examinations or procedures performed during these visits, 105 million were radiographic, 54 million dental, 10.5 million fluoroscopic, and 3.5 million X-ray therapy. The estimated number of X-ray films taken were 506 million.

The significance of X-ray exposure to a population became evident in early studies made to determine the magnitude of radiation resulting from nuclear weapons testing programs. To date, estimates of exposure to medical and dental X radiation have been available only on selected groups and could not be applied to the general population with any reasonable degree of certainty. The X-ray Exposure Study was undertaken to obtain information on the X-ray experience of a representative sample of the U.S. population in order to estimate X-ray exposure and dose for the general population.

In 1961, the National Center for Health Statistics in cooperation with the National Center for Radiological Health, collected information on the medical and dental X-ray experience for a representative sample of the civilian noninstitutional population residing in the United States (*1*). This survey demonstrated the feasibility of collecting X-ray visit data by household interviews. The "Field Trial of a System to Obtain Data on Population Exposure to X-rays" (*2*) describes the preliminary test of a complete reporting system including household interviews, facility contact by questionnaire, and the use of film packs as a corroborating vehicle on reported technical factors, as well as beam size and alignment. Based on this field trial, it was concluded that the X-ray Exposure Study would provide estimates of population exposure to X rays and that data compatible with university research in dose model development could be obtained.

The following is a summary of selected information from *Population Exposure to X-rays, U.S. 1964. A Report on the Public Health Service X-ray Exposure Study.* Public Health Service Publication No. 1519. A complete report of the methods and procedures used may be found in that document.

The study had two major phases: (1) the household interview survey from which the X-ray experience of the population was obtained, and (2) a followup by mail to the place where an X-ray visit was reported in the household survey. The facility was requested to provide information on the equipment used, type of examination, machine settings, and to expose an enclosed film pack replicating the first exposure recorded on the questionnaire. The household interview phase provided data which could be compared with the 1961 visit data together with the socioeconomic and demographic

[1] Prepared by Mrs. Myrtle C. Sydenstricker, Public Health analyst, Population Exposure Studies, Population Studies Program, National Center for Radiological Health, Rockville, Md.

characteristics of the population surveyed. The facility followup phase provided technical information on examinations and procedures and films or exposures.

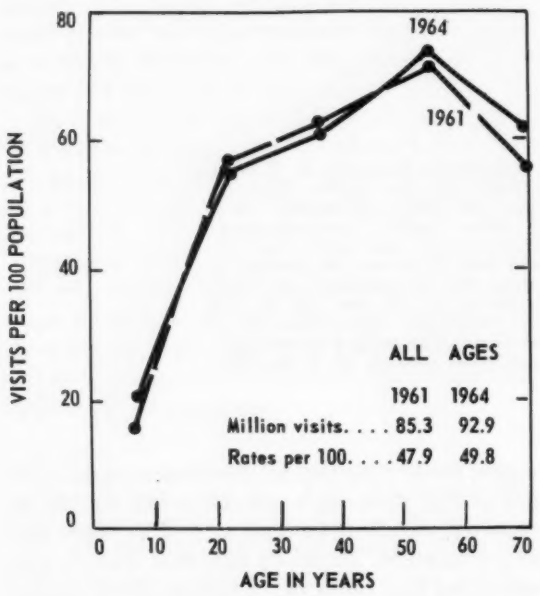

Figure 1. Estimated annual rate of medical X-ray visits by age, 1961 and 1964

An estimated 108 million, or 58 percent of the 187 million civilian noninstitutional population of the United States had one or more X-ray visits in 1964. These visits were estimated to be 93 million medical and 50 million dental. Between 1961 and 1964, the annual number of medical X-ray visits increased by 8 percent and, in terms of the annual rate of visits per 100 population, from 47.9 visits in 1961 to 49.8 in 1964. The increase occurred among children under 15 and among older adults particularly those 65 years and over (figure 1). The annual dental X-ray visit rate declined from 27.4 visits per 100 persons in 1961 to 26.8 per 100 in 1964.

The estimated annual X-ray experience of the U.S. population is shown in figure 2 for visits, examination and procedures, and films or exposures by type of X-ray visit (about 12 million persons had more than one category of X-ray procedure). An estimate of persons X-rayed during medical and dental visits according to geographic region and sex (*5*) is presented in figures 3 and 4.

The higher annual rate of medical X-ray visits in the West may be due to the greater percent of visits to physicians' offices in this region, 33 percent in contrast to 23 or 24 percent in other regions. This finding is consistent

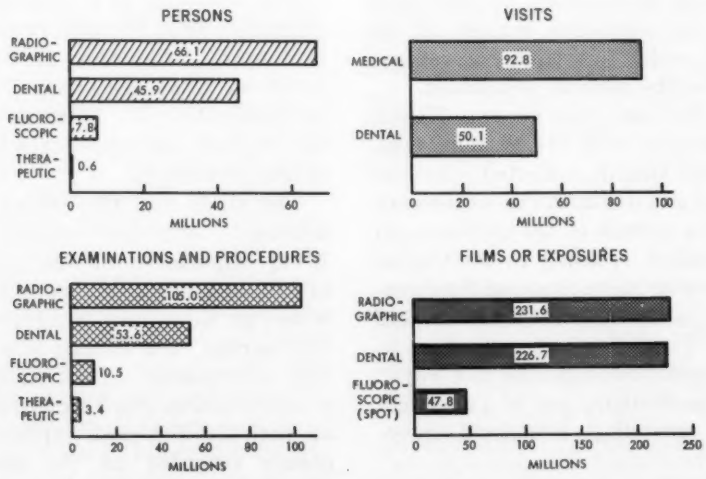

Figure 2. Estimated annual X-ray experience of the population by number of persons, visits, examinations and procedures, films or exposures, 1964

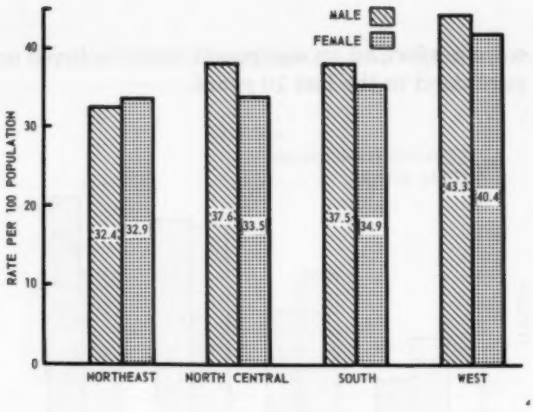

Figure 3. Estimated annual rate of medical X-ray visits (by region and sex)

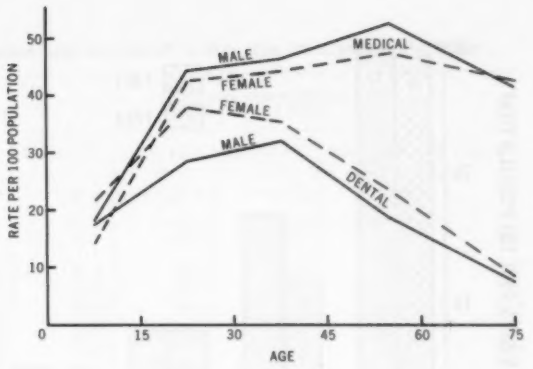

Figure 5. Estimated annual rates of medical and dental X-ray visits (by age and sex)

with other survey data on the use of out-of-hospital services of physicians in the West. The rate of persons X-rayed during dental visits in the North Central and South regions presents a reverse picture to that for medical X-ray visits in the same areas.

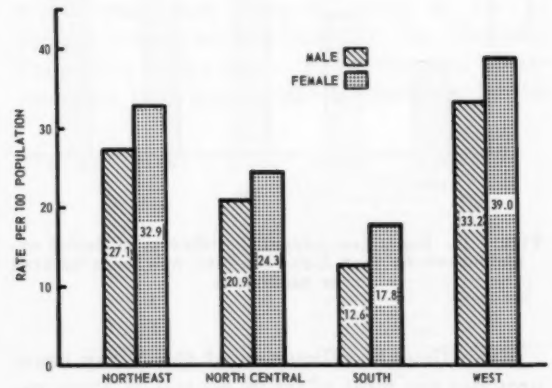

Figure 4. Estimated annual rate of dental X-ray visits (by age and sex)

Analysis of each type of procedure by age and sex (figure 5) reveals the rate for males X-rayed during medical visits to be higher than the rate for females. However, the annual rate for females X-rayed during dental visits is consistently higher than the rate for males over all age groups.

The estimated annual rate of persons X-rayed during medical visits was relatively constant over the various family income groups; whereas the annual rate of persons X-rayed during dental visits rises sharply as income increases (figure 6).

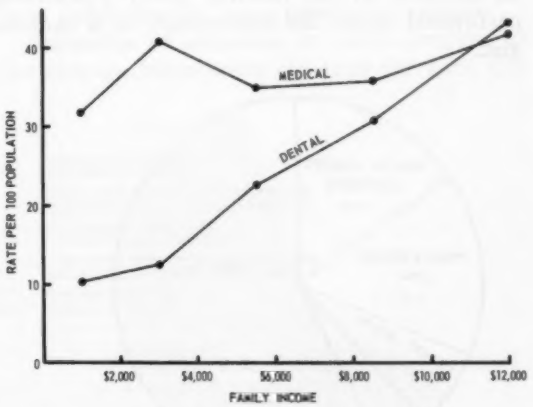

Figure 6. Estimated annual rate of medical and dental X-ray visits by family income

The observed increase in medical X-ray visits between 1961 and 1964 (figure 1) is reflected in the areas of the body examined (figure 7); the predominant increase being in visits involving abdominal X rays, most common among older persons.

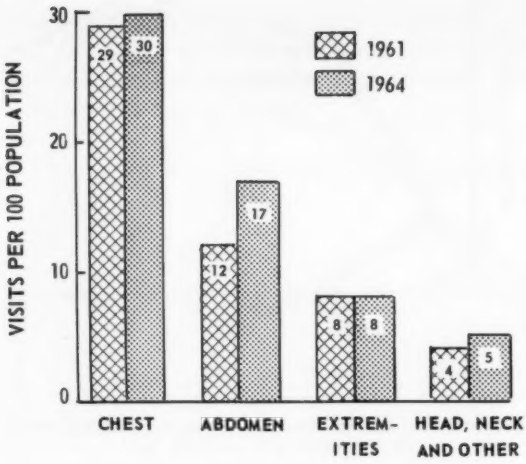

Figure 7. Estimated annual rate of medical X-ray visits by area of the body X rayed, 1961 and 1964

Fifty-eight percent of the medical X-ray procedures were performed in hospitals. Figure 8 also shows the percent distribution for other facilities where medical X-ray procedures were reported. In addition, the shaded area provides an estimate of the medical X-ray procedures performed under the supervision of a radiologist.

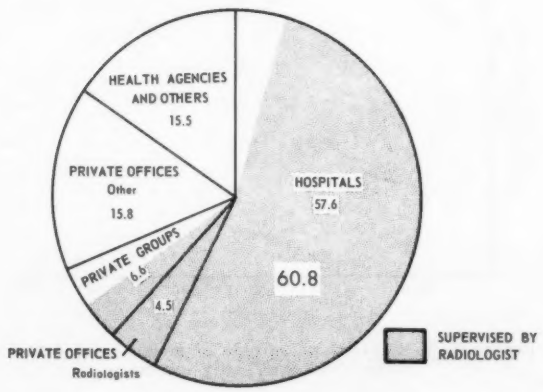

Figure 8. Estimated percent distribution of medical X-ray procedures by type of facility and supervision

Equipment proved to be of recent age (figures 9 and 10); almost 70 percent of the radiographic examinations reported in the study were performed on equipment manufactured or purchased in the last 10 years.

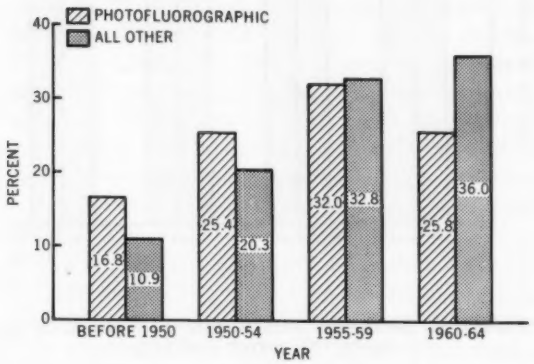

Figure 9. Estimated percent distribution of photofluorographic and radiographic examinations by year X-ray machine was manufactured or purchased

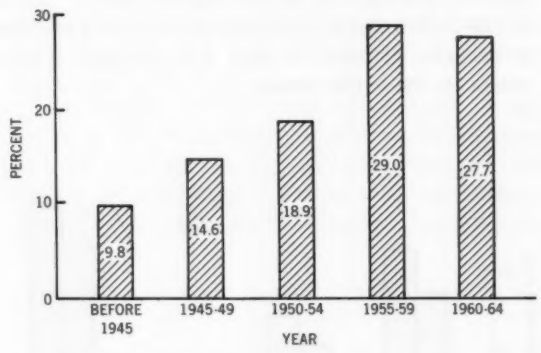

Figure 10. Estimated percent distribution of dental examinations by year X-ray machine was manufactured or purchased

Even though collimation of the X-ray beam provides the most effective control of stray radiation, more than one-half of all radiographic films had a beam size in excess of the reported film area plus a 25-percent allowance (table 1). More than 25 percent of these exposures were associated with beam areas that were two or more times larger than the film area plus the allowance. These excess beam sizes are an important finding of the study, since radiation not interrupted by a film or fluorescent screen is unnecessary radiation. Although misalignment can contribute to excess beam area, it did

Table 1. Percent distribution of radiographic film packs[a] by beam area as related to film area for reported film sizes

Film size	Number of films	Film area plus allowance[b] (percent of films)				
		Within 1X	1.0 to 1.9X	2.0 to 3.9X	4.0 to 5.9X	6X and over
All sizes	2,147	45.3	33.1	13.2	5.0	3.1
Photofluorographic	490	51.2	46.1	2.7	0.0	0.0
Radiographic	1,657	43.6	29.2	16.3	6.9	4.0
14 by 17	934	44.4	30.6	14.6	7.6	2.8
10 by 12	304	53.3	28.0	15.1	1.0	2.6
8 by 10	172	36.6	25.6	22.7	12.2	2.9
11 by 14	63	54.0	36.5	6.3	0.0	3.2
5 by 12	39	17.9	46.2	20.5	12.8	2.6
4 by 10	35	17.1	28.6	25.7	14.3	14.3
5 by 7	20	15.0	5.0	30.0	20.0	30.0
Others	90	36.7	18.9	24.4	5.6	14.4

[a] One hundred and eighty-three of the 2,330 film packs are excluded due to not calculable or not stated variables.
[b] Includes an additional 25 percent allowance for comparison with beam area.

not appear to be an important factor in contributing to beam areas that are larger than necessary. The International Commission on Radiological Protection has stated that use of light beam localizing devices would increase the accuracy with which a technician can direct the primary beam (*3*). In figure 11, no allowance of beam size has been added to film area.

Approximately 80 percent of the dental exposures recorded in the study were within the 3-inch maximum beam diameter at tip of pointer cone recommended by the National Committee on Radiation Protection and Measurements (*4*). Survey efforts sponsored by the U.S. Public Health Service indicate a continuing upward trend in the proportion of dental X-ray examinations within recommended beam diameters.

Of the 10.5 million fluoroscopic examinations, about 56 percent were gastrointestinal series and approximately 30 percent were barium enemas. Only 1 percent of the fluoroscopic examinations were performed at a source-to-tabletop distance of less than 12 inches. Thus, it appears that fluoroscopic machine design has been influenced by recommended standards.

Estimates of exposure in milliroentgens at the skin entrance were obtained for each film

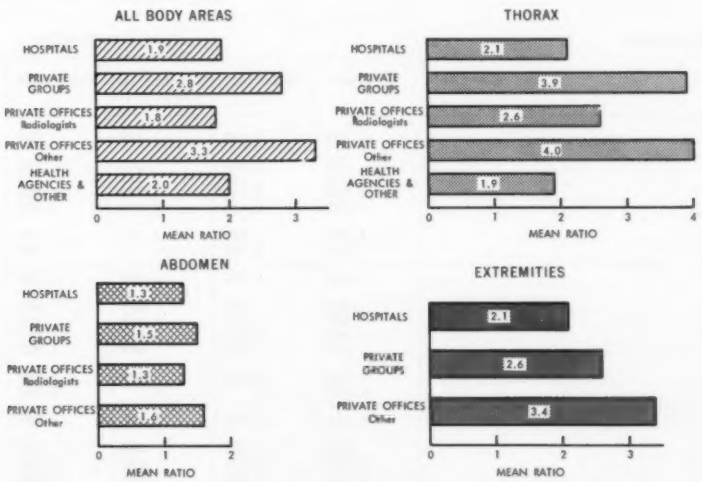

Figure 11. Estimated mean ratio of beam area to film area for radiographic films for selected body areas by type of facility

or exposure reported in the study. Mathematical models generated reference tables of mean milliroentgens per milliampere-second at 12 inches for varying kVp-filtration combinations necessary for assigning values, adjusted for body-part thickness (radiographic), to each recorded exposure. These estimates of exposure were produced to the nearest milliroentgen, although this precision should not be associated with these averages.

Estimated mean exposure values per film associated with dental examinations are given in table 2 and for radiographic examinations in table 3. For dental films, there is little difference in the average exposure per film by type of examination whereas, as one might expect, delineation of bony structures is associated with higher exposure values for radiographic films.

Estimates of exposure during fluoroscopic examinations were obtained by means of large-film dosimetry used during a subsequent similar procedure at the reported facility. Exposure per unit area resulted. Further development of this concept is being pursued through cooperative effort with the several universities engaged in X-ray dose model research.

Although the X-ray Exposure Study does not contain genetic or organ dose estimates for the U.S. population, work is currently underway to develop such data by age, sex, and type of X-ray procedure for presentation in the near future.

REFERENCES

(1) NATIONAL CENTER FOR HEALTH STATISTICS. Volume of X-ray visits, U.S., July 1960–June 1961. Series B–No. 38, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C. 20201 (1962).

(2) GITLIN, J. N., C. R. HAYMAN, E. G. PROCTOR, and P. L. RONEY. Field trial of a system to obtain data on population exposure to X-rays. Public Health Rep 79:185–192 (March 1964).

(3) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Exposure of man to ionizing radiation arising from medical procedures. Physics Med Biol 2:107–156 (1957).

(4) U.S. DEPARTMENT OF COMMERCE. Medical X-ray protection up to three million volts. National Bureau of Standards Handbook 76. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20401 (1961).

(5) U.S. BUREAU OF THE CENSUS. U.S. Census of Population: 1960, Final Report, PC(1)–1A. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20401.

Table 2. Estimated mean exposure per dental film by type of examination, sex, and age, 1964

Sex and age	Milliroentgens (at skin entrance)					
	Type of examination					
	All types	Bitewing	Bitewing and periapical	Full mouth	Periapical	All other
Both sexes	1,138	1,249	1,170	1,059	1,201	1,302
Under 15	876	1,067	600	763	865	1,339
15 to 29	1,149	1,324	1,417	939	1,375	(a)
30 to 44	1,153	1,161	1,372	1,078	1,319	(a)
45 and over	1,377	1,635	1,204	1,385	1,167	(a)
45 to 64	1,397	1,669	1,179	1,379	1,244	(a)
65 and over	1,246	1,249	(a)	1,433	978	(a)
Male	1,134	1,122	1,175	1,136	1,141	746
Under 15	833	996	471	839	683	(a)
15 to 29	1,021	1,357	1,377	723	1,202	(a)
30 to 44	1,205	1,131	1,844	1,096	1,354	(a)
45 and over	1,517	997	922	1,825	1,417	(a)
45 to 64	1,518	1,024	824	1,888	1,043	(a)
65 and over	1,513	(a)	(a)	1,399	2,473	(a)
Female	1,141	1,345	1,166	997	1,248	1,828
Under 15	912	1,137	754	714	1,017	(a)
15 to 29	1,252	1,301	1,459	1,109	1,533	(a)
30 to 44	1,110	1,184	998	1,063	1,286	(a)
45 and over	1,274	1,960	1,373	969	1,203	(a)
45 to 64	1,305	2,009	1,373	923	1,410	(a)
65 and over	1,069	1,494	(a)	1,482	736	(a)

(a) Outside confidence limits.

Table 3. Estimated mean exposure per film by type of radiographic[a] examination and type of facility, 1964

Type of examination	Milliroentgens (at skin entrance)					
	All	Hospitals	Private offices		Private groups	Health agencies and others
			Radiologists	Others		
Head and neck	279	277	341	277	256	[b]
Skull	304	312	[b]	[b]	[b]	[b]
Cervical spine	158	113	[b]	294	[b]	[b]
Head and neck, n.e.c.	370	363	[b]	[b]	[b]	[b]
Thorax						
Chest, photofluorographic	504	408	[b]	[b]	[b]	[c] 521
Chest, radiographic	45	43	34	44	43	92
Shoulder	213	193	[b]	[b]	[b]	[b]
Thoracic spine and cervical spine	1,265	1,371	[b]	[b]	[b]	[b]
Chest or thorax, n.e.c.	1,657	1,998	[b]	[b]	[b]	[b]
Abdomen	790	743	636	1,253	736	1,484
Upper abdomen	796	747	533	1,475	684	[b]
Cholecystography or cholangiogram	771	740	[b]	[b]	612	[b]
Lumbar spine or dorsolumbar spine	1,965	2,005	[b]	2,295	[b]	[b]
Upper gastrointestinal series	519	514	456	[b]	567	[b]
Gastrointestinal, n.e.c.	521	466	[b]	[b]	[b]	[b]
Upper abdomen, n.e.c.	363	365	[b]	[b]	[b]	[b]
Lower abdomen	784	738	770	1,102	789	[b]
Barium enema	629	652	530	[b]	[b]	[b]
Abdomen, KUB, flat plate	771	773	[b]	[b]	[b]	[b]
Intra- or retrograde pyelogram	481	468	[b]	597	444	[b]
Pelvis or lumbo-pelvic	487	438	[b]	[b]	[b]	[b]
Lumbosacral or sacral spine	2,449	2,466	[b]	[b]	[b]	[b]
Hip	1,036	1,279	[b]	[b]	[b]	[b]
Extremities	117	118	113	138	63	73
Upper extremities	127	136	[b]	134	49	[b]
Hand and/or wrist	82	93	[b]	76	[b]	[b]
Forearm or elbow	125	86	[b]	279	[b]	[b]
Lower extremities	110	105	[b]	141	71	[b]
Ankle	109	104	[b]	165	[b]	[b]
Foot and toes or heel	126	104	[b]	195	[b]	[b]
Knee	93	85	[b]	79	[b]	[b]
Tibia and fibula	44	47	[b]	[b]	[b]	[b]
Femur or entire leg	187	202	[b]	[b]	[b]	[b]

[a] Includes photofluorographic exposures.
[b] Outside confidence limits.
[c] Comprises mean exposure values of 545 for mobile units and 454 for stationary units.
NOTE: n. e. c., not elsewhere classified.

SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Both Federal and State agencies are involved in efforts to continuously monitor the intake of radionuclides from the diet. The most direct measure of radionuclide intake would be through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternate method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake for the short-lived radionuclides. For these reasons, milk is the single food item most often used in estimating the intake of selected radionuclides by the general population and/or specific population groups. In the absence of specific dietary information, one may assume the total daily dietary intake of selected radionuclides is equivalent to the intake represented by the consumption of 1 liter of milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5,6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

REFERENCES

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(*2*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1960).

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action for strontium–89, strontium–90, and cesium–137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402 (May 1965).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(*5*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 2. Pergamon Press, New York, N.Y. (1959).

(*6*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 6. Pergamon Press, New York, N.Y. (1965).

National and International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk. In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	January–June 1966	March 1967

1. Pasteurized Milk Network
March 1967

National Center for Radiological Health and *National Center for Urban and Industrial Health, PHS*

The Public Health Service's Pasteurized Milk Network (PMN), was designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 stations (figure 1) provides data on milk in every State, the Canal Zone, and Puerto Rico. The most recent descrip-

Table 1. Analytical errors associated with determination of radionuclide concentrations in milk

Nuclide	Concentration (pCi/liter)	Error * (pCi/liter)	Concentration (pCi/liter)	Error * (percent of concentration)
Iodine-131	Less than 100	10	100 or greater	10
Barium-140	Less than 100	10	100 or greater	10
Cesium-137	Less than 100	10	100 or greater	10
Strontium-89	Less than 50	5	50 or greater	10
Strontium-90	Less than 20	2	20 or greater	10

* Two standard deviations.

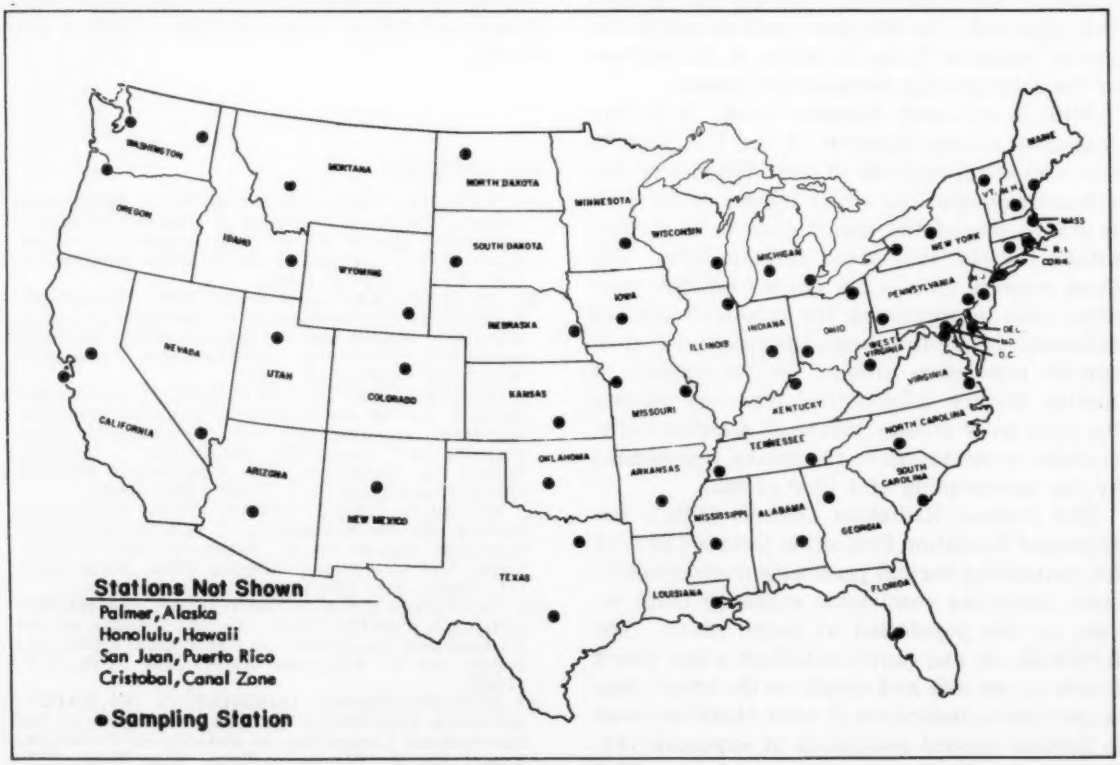

Figure 1. Pasteurized Milk Network sampling stations

Table 2. Average concentrations of radionuclides in pasteurized milk for March 1967 and the first quarter 1967

Sampling location		Strontium-89 (pCi/liter)		Strontium-90 (pCi/liter)		Iodine-131 (pCi/liter)		Cesium-137 (pCi/liter)		Barium-140 (pCi/liter)	
		March [a] 1967	First quarter 1967	March 1967	First quarter 1967	March 1967	First quarter 1967	March 1967	First quarter 1967	March 1967	First quarter 1967
Ala:	Montgomery	< 5	<5	13	12	0	10	15	15	0	0
Alaska:	Palmer	< 5	<5	9	9	0	0	20	20	0	0
Ariz:	Phoenix	< 5	<5	3	2	0	0	< 5	< 5	0	0
Ark:	Little Rock	< 5	<5	23	23	0	0	25	20	0	0
Calif:	Sacramento	5	<5	3	3	0	0	< 5	< 5	0	0
	San Francisco	10	<5	4	4	0	0	5	< 5	0	0
C. Z:	Cristobal	< 5	<5	5	6	0	0	25	25	0	0
Colo:	Denver	< 5	<5	6	6	0	0	< 5	< 5	0	0
Conn:	Hartford			9	10	0	0	25	25	0	0
Del:	Wilmington			11	11	0	0	20	20	0	0
D. C:	Washington	< 5	<5	10	10	0	0	15	15	0	0
Fla:	Tampa	< 5	<5	9	9	0	0	65	70	0	0
Ga:	Atlanta	< 5	<5	16	17	0	10	25	25	0	0
Hawaii:	Honolulu	< 5	<5	6	5	0	0	20	15	10	0
Idaho:	Idaho Falls	< 5	<5	7	7	0	0	10	10	0	0
Ill:	Chicago	< 5	<5	10	9	0	0	25	20	0	0
Ind:	Indianapolis		<5	11	10	0	0	20	20	0	0
Iowa:	Des Moines	< 5	<5	9	9	0	0	10	10	0	0
Kans:	Wichita	< 5	<5	9	9	0	0	5	5	0	0
Ky:	Louisville	< 5	<5	14	15	0	0	15	15	0	0
La:	New Orleans	10	<5	31	28	0	0	35	35	0	0
Maine:	Portland		<5	12	13	0	0	40	45	0	0
Md:	Baltimore	< 5	<5	11	11	0	0	20	20	0	0
Mass:	Boston	< 5	<5	12	13	0	0	35	35	0	0
Mich:	Detroit			10	10	0	0	20	20	0	0
	Grand Rapids		<5	12	11	0	0	20	25	0	0
Minn:	Minneapolis	< 5	<5	14	14	0	0	10	15	0	0
Miss:	Jackson	10	<5	21	22	0	10	20	20	0	0
Mo:	Kansas City	< 5	<5	11	10	0	0	< 5	5	0	0
	St. Louis	< 5	<5	11	11	0	0	10	10	0	0
Mont:	Helena	< 5	<5	7	7	0	0	10	10	0	0
Nebr:	Omaha	< 5	<5	9	10	0	0	10	10	0	0
Nev:	Las Vegas	< 5	<5	3	3	0	0	< 5	< 5	0	0
N. H:	Manchester		<5	15	16	0	0	50	45	0	0
N. J:	Trenton		<5	10	10	0	0	20	25	0	0
N. Mex:	Albuquerque	< 5	<5	5	5	0	0	< 5	< 5	0	0
N. Y:	Buffalo		<5	9	9	0	0	20	20	0	0
	New York		<5	11	11	0	0	20	20	0	0
	Syracuse		<5	9	9	0	0	25	20	0	0
N. C:	Charlotte	< 5	<5	19	18	0	0	20	20	0	0
N. Dak:	Minot	< 5	<5	17	17	0	0	15	15	0	0
Ohio:	Cincinnati		<5	11	11	0	0	20	20	0	0
	Cleveland		<5	11	12	0	0	20	20	0	0
Okla:	Oklahoma City	< 5	<5	10	11	0	0	10	10	0	0
Ore:	Portland	< 5	5	8	8	0	0	5	10	0	0
Penn:	Philadelphia		<5	11	11	0	0	20	20	0	0
	Pittsburgh			13	13	0	0	25	25	0	0
P. R:	San Juan	< 5	<5	6	5	0	0	15	15	0	0
R. I:	Providence		<5	11	11	0	0	30	30	0	0
S. C:	Charleston	< 5	<5	17	19	0	20	30	30	0	0
S. Dak:	Rapid City	< 5	<5	10	11	0	0	10	15	0	0
Tenn:	Chattanooga	< 5	<5	16	17	0	0	20	20	0	0
	Memphis	< 5	<5	12	13	0	0	10	10	0	0
Tex:	Austin	< 5	<5	3	4	0	20	5	10	0	0
	Dallas	< 5	<5	9	9	0	10	10	10	0	0
Utah:	Salt Lake City	< 5	<5	6	7	0	0	10	10	0	0
Vt:	Burlington		<5	11	11	0	0	25	25	0	0
Va:	Norfolk	< 5	<5	12	13	0	0	15	15	0	0
Wash:	Seattle	< 5	<5	14	11	0	0	25	25	0	0
	Spokane	< 5	<5	11	11	0	0	20	20	0	0
W. Va:	Charleston	< 5	<5	11	13	0	0	15	15	0	0
Wisc:	Milwaukee			8	8	0	0	20	20	0	0
Wyo:	Laramie	< 5	<5	4	7	0	0	< 5	10	0	0
Network average		< 5	<5	10.7	10.8	0	0	20	20	0	0

[a] Blank indicates no strontium-89 determinations were made on samples from station during month.

tion of the sampling and analytical procedures employed by the PMN appeared in the December 1966 issue of *Radiological Health Data and Reports* (*1*).

Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. The results for March 1967 and first quarter of 1967 are presented in table 2. The average monthly radionuclide concentrations are based on results obtained from samples collected weekly. If radionuclide values were below minimum detectable concentrations (*1*), averages were calculated using one-half the minimum detectable values; however, for iodine–131 and barium–140, zero was used for averaging purposes when concentrations were below minimum detectable levels.

For comparative purposes, distributions of strontium–90 and cesium–137 are presented in tables 3 and 4 for March 1966 and October 1966 through March 1967. The average strontium–90 concentrations in pasteurized milk from selected cities are presented in figure 2.

Table 3. Frequency distribution of monthly average strontium-90 concentrations in milk at PMN stations, March 1966, October–December 1966, and January–March 1967

Strontium-90 (pCi/liter)	Number of stations						
	1966				1967		
	Mar	Oct	Nov	Dec	Jan	Feb	Mar
Under 10	9	18	19	23	24	21	25
10–19	44	39	40	35	36	38	35
20–29	7	6	4	5	3	4	2
30–39	3	0	0	0	0	0	1

Table 4. Frequency distribution of monthly average cesium-137 concentration in milk at PMN stations, March 1966, October–December 1966, and January–March 1967

Cesium-137 (pCi/liter)	Number of stations						
	1966				1967		
	Mar	Oct	Nov	Dec	Jan	Feb	Mar
Under 50	56	62	61	62	62	62	62
50–99	6	0	2	1	1	1	1
100–149	1	1	0	0	0	0	0

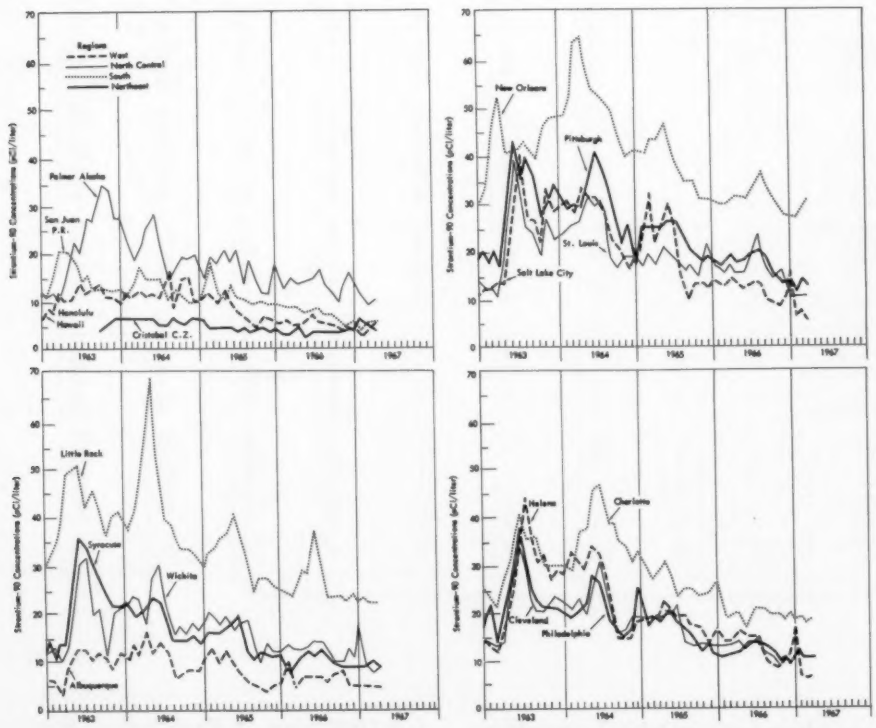

Figure 2. Strontium–90 concentrations in pasteurized milk, 1961–March 1967

2. Canadian Milk Network March 1967 [1]

Radiation Protection Division
Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the December 1966 issue of *Radiological Health Data and Reports* (*2*).

The March 1967 monthly average strontium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 5. Iodine–131 and strontium–89 concentrations were below minimum detectable levels.

[1] Prepared from April 1967 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 5. Stable elements and radionuclides in Canadian whole milk, March 1967

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.17	1.4	12.7	37
Edmonton	1.14	1.5	11.0	38
Ft. William	1.13	1.5	17.2	44
Fredericton	1.13	1.4	16.1	42
Halifax	1.17	1.6	16.6	40
Montreal	1.11	1.5	10.6	29
Ottawa	1.17	1.5	10.8	25
Quebec	1.10	1.5	14.8	53
Regina	1.16	1.5	10.0	26
St. John's, Nfld.	1.11	1.6	20.2	56
Saskatoon	1.16	1.5	12.4	32
Sault Ste. Marie	1.12	1.6	15.5	40
Toronto	1.15	1.4	7.0	19
Vancouver	1.20	1.6	17.2	70
Windsor	1.18	1.5	6.2	21
Winnipeg	1.18	1.6	10.8	36
Average	1.15	1.5	13.1	38

Figure 3. Canadian milk sampling stations

3. Pan American Milk Sampling Program March 1967

Pan American Health Organization and *U.S. Public Health Service*

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American Republics in developing national radiological health programs.

Under a joint agreement between agencies, air and milk sampling activities are conducted by a numer of PAHO member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1966 issue of *Radiological Health Data and Reports* (*3*).

Table 6 presents stable calcium and potassium, strontium–90, and cesium–137 monthly average concentrations for March 1967.

Figure 4. Pan American Milk Sampling Program stations

Table 6. Stable element and radionuclide concentration in PAHO milk [a] March 1967

Sampling station	Number of samples	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Chile: Santiago	4	1.52	<1	11
Colombia: Bogota	1	1.28	1	15
Ecuador: Guayaquil, Mar 1967	4	1.43	<1	10
Jan 1967	4	1.35	<1	< 5
Feb 1967	4	1.44	<1	< 5
Jamaica: Kingston	NS			
Mandeville	NS			
Montego Bay	NS			
Venezuela: Caracas, Mar 1967	1	1.41	4	10
Dec 1966	1	1.35	3	10
Jan 1967	1	1.34	5	10
Feb 1967	1	1.46	2	< 5
Canal Zone: Cristobal [c]	4		5	25
Puerto Rico: San Juan [c]	4		6	15

[a] Iodine-131 and barium-140 determinations were less than 10 pCi/liter for all samples. Strontium-89 was less than 5 pCi/liter for all samples.
[b] Data not previously presented.
[c] For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico, from the Pasteurized Milk Network, are presented.
NS, no sample collected.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, August 1966. Radiol Health Data Rep 7: 698–701 (December 1966).

(*2*) RADIATION PROTECTION DIVISION, DEPARTMENT OF NATIONAL HEALTH AND WELFARE. Canadian milk network, August 1966. Radiol Health Data Rep 7:702–703 (December 1966).

(*3*) PAN AMERICAN HEALTH ORGANIZATION and U.S. PUBLIC HEALTH SERVICE. Pan American Milk Sampling Program, August 1966. Radiol Health Data Rep 7:704 (December 1966).

State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States have established comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

In addition to the State milk networks presented herein, programs previously covered in *Radiological Health Data and Reports* include:

State milk network	Period reported	Last presented
California	October–December 1966	June 1967
Connecticut	October–December 1966	May 1967
Indiana	October–December 1966	May 1967
Michigan	October–December 1966	May 1967
Minnesota	October–December 1966	May 1967
Oregon	October–December 1966	June 1967
New York	October–December 1966	May 1967
Pennsylvania	October–December 1966	May 1967
Washington	October–December 1966	June 1967

1. Colorado Milk Network January–March 1967

Occupational and Radiological Health Division
Colorado State Department of Public Health

The Radiological Health Division of the Colorado State Department of Public Health initiated radiological analysis of milk in January 1962. Initially, the Denver City and County Health Department collected a weekly composite milk sample from the major producers in the Denver area for the State, as it had for the Public Health Service since March 1960.

In August 1962, the State expanded its program to include the routine sampling of raw milk from the four major milk producing areas supplying the State: northeast, southeast, western Colorado, and eastern Utah. Areas of the State presently sampled are western, south central, northeastern, and eastern Colorado (including northwestern Kansas). Colorado milkshed areas are shown in figure 1.

Recent analyses have been on samples of raw milk coming into the State Health Department specifically for gamma-ray analysis. January sampling was intensified in response to the mainland Chinese atmospheric nuclear test of December 1966.

Analyses are performed for iodine–131, barium–140, cesium–137, and potassium by gamma-ray spectroscopy. The measurement system previously reported upon (*1*) has been adapted to utilize a 4- by 5-inch NaI crystal shielded by a lead-lined bank safe.

Minimum detectable amounts at the 2σ counting error equivalent are iodine–131 (10 pCi/liter); barium-lanthanum–140 (15 pCi/liter); cesium–137 (10 pCi/liter); and potassium (0.2 g/liter).

Table 1 gives results of the measurements of radionuclides in milk collected from January through March 1967. Barium-lanthanum–140 was not detected during this period. Analyses for the last half of 1966 were not reported due to a temporary curtailment of the program during that period.

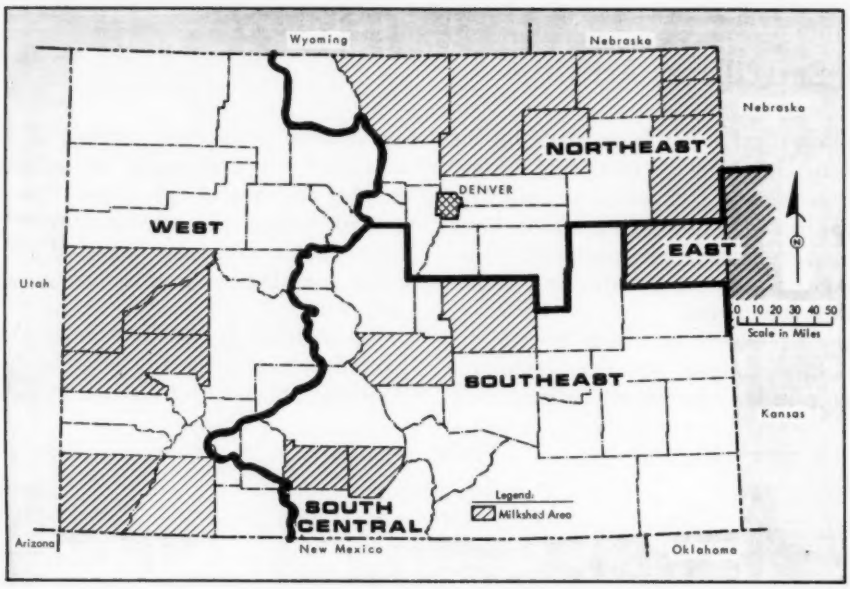

Figure 1. Colorado milk sampling areas

Table 1. Radionuclides in Colorado raw milk, January–March 1967

Date of sampling 1967	Area sampled [a]	Number of samples analyzed	Number of samples containing detectable radionuclides [b]	Concentration of detectable radionuclides (pCi/liter)	
				Iodine-131	Cesium-137
January 3	W	2			
4	W	4	1		16
4	NE	7			
4	E	1			
5	W	1			
8	W	1			
10	W	1			
12	E	1			
12	NE	11			
February 27	NE	2	2		13, 15
27	E	1			
28	NE	2	1		14
28	W	2	1	16	12
March 20	E	1			
21	NE	1			
22	NE	1			
23	NE	1			
27	W	1			

[a] W—western Colorado
NE—northeastern Colorado
E—eastern Colorado (including northwestern Kansas)

[b] Minimum detectable activity is taken as equal to or greater than the 2σ counting error equivalent and for the two radionuclides given is 10 pCi/liter.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1964 and summaries 1962–1964	April 1965
May 1965–June 1966	October 1966

2. Oklahoma Milk Network January–March 1967

Oklahoma State Department of Health [1]

On March 15, 1965, the Radiological Health Section of the Oklahoma State Department of Health initiated a program of analysis for iodine–131 in the milk produced in the State of Oklahoma.

The location of the sampling stations and the extent of their associated milksheds are shown in figure 2. Of the 10 milksheds in the State of Oklahoma, 5 were chosen as sampling stations (Oklahoma City, Enid, Tulsa, Lawton, and Ardmore) on the basis of their size and location. A major criterion in the selection of a milkshed for sampling was the degree of overlap with other milksheds being sampled. This overlap assists in locating small areas of production where the iodine–131 concentrations might be abnormally high.

The sampling stations are located in the laboratory of a major milk processing plant in each milkshed. While the milkshed for a particular processing plant may not coincide exactly with that shown in figure 2 the coincidence is satisfactory for surveillance purposes.

[1] Acknowledgement is accorded to the staff of the Radiological Health Section under the direction of Mr. Dale McHard, head, and Mr. Robert Craig, assistant engineer.

At the present time, samples are collected on Monday morning, and the analyses are completed by Wednesday afternoon. However, if iodine–131 levels detected are such that diversion of the milk or other precautionary methods need to be taken, the analytical method and equipment can be employed to sample each truck arriving at the processing plant. Under these conditions, only about 4 hours would be needed to complete the analysis. This greatly reduced lag time for analysis would permit rapid decisions on the fate of each truckload of raw milk.

Analytical method

The method of analysis is similar to that recently published by the U.S. Public Health Service (*2*) but was developed independently by the Oklahoma State Health Department's Radiological Health Laboratory.

Results and discussion

Table 2 gives the concentrations of iodine–131 found in Oklahoma milk samples collected from January through March 1967. Cesium–137 concentrations are presented in table 3.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	January 1967
October–December 1966	April 1967

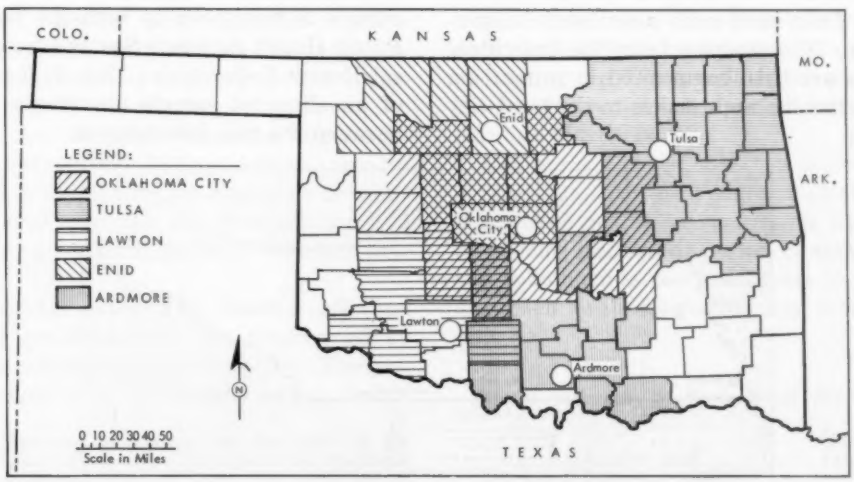

Figure 2. Oklahoma milkshed sampling areas

Table 2. Concentration of iodine-131 in Oklahoma pasteurized milk, January–March 1967

Sampling date 1967	Sampling location Radionuclide concentrations (pCi/liter)				
	Oklahoma City	Enid	Tulsa	Lawton	Ardmore
January 2	IF	IF	IF	IF	IF
9	24	54	3	2	56
16	10	NS	23	NS	NS
23	4	NS	9	ND	ND
30	ND	6	4	ND	4
February 10	ND	ND	12	12	ND
17	ND	ND	ND	ND	ND
24	ND	ND	9	ND	ND
March 3	ND	ND	ND	ND	ND
10	ND	ND	ND	ND	ND
17	ND	ND	12	11	12
24	ND	ND	ND	ND	ND
31	ND	ND	ND	ND	ND

IF, instrument failure.
NS, no sample collected.
ND, nondetectable, less than 3 pCi/liter.

Table 3. Concentration of cesium-137 in Oklahoma pasteurized milk, January–March 1967

Sampling date 1967	Sampling location Radionuclide concentration (pCi/liter)				
	Oklahoma City	Enid	Tulsa	Lawton	Ardmore
January 2	IF	IF	IF	IF	IF
9	ND	59	ND	ND	14
16	ND	NS	17	NS	NS
23	12	NS	ND	ND	ND
30	ND	ND	ND	13	ND
February 10	ND	ND	15	36	ND
17	ND	73	24	ND	9
24	ND	ND	39	ND	ND
March 3	ND	ND	ND	18	ND
10	17	ND	ND	ND	ND
17	10	35	19	ND	ND
24	11	13	ND	ND	ND
31	13	12	17	ND	ND

IF, instrument failure.
ND, not detectable—less than 10 pCi/liter.
NS, no sample collected.

3. Tennessee Milk Network January–March 1967

Division of Preventable Diseases
Department of Public Health
State of Tennessee

The Tennessee Department of Public Health began sampling pasteurized milk for radionuclide analysis in July of 1965. Currently the Department is collecting semimonthly milk samples from three cities (figure 3). In order to obtain a representative sample the milk consumed in the areas monitored, a sample of milk is collected from each milk distributor supplying the city. The samples from the individual distributors are then composited in proportion to the contribution each makes to the total city milk supply.

Analytical procedures

The semimonthly milk samples from each city sampled are analyzed by gamma-ray scintillation spectrometry for potassium–40, iodine–131, cesium–137, and barium–140, using a 3½-liter sample. After gamma-ray analysis, the samples are stored for 2 weeks to allow ingrowth of daughter activity, after which strontium–89, strontium–90, and barium–140 concentrations are determined radiochemically using ion exchange procedures. Chemical analyses are also made for stable calcium and potassium.

It can be noted that the Chattanooga milk sample is monitored by both the State and the Public Health Service's Southeastern Radiological Health Laboratory. This dual examination of an aliquoted sample provides a cross-check between the two laboratories.

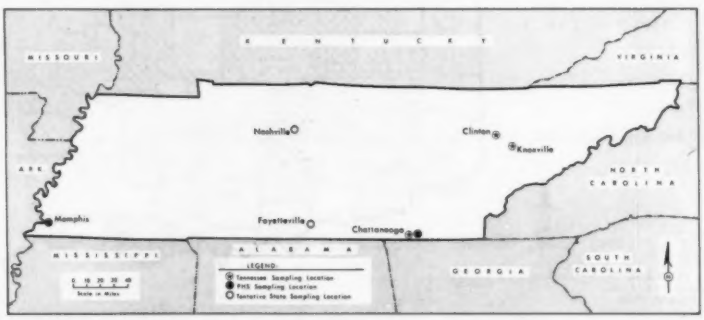

Figure 3. Tennessee pasteurized milk sampling stations

Results

The monthly average stable element and radionuclide concentrations in Tennessee pasteurized milk are presented in table 4 for the period of January through March 1967.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July 1965–June 1966	April 1967

Table 4. Radionuclides in Tennessee pasteurized milk, January–March 1967

Location	Month 1967	Concentration (g/liter)	Radionuclide concentration (pCi/liter)				
		Potassium	Strontium-89	Strontium-90	Iodine-131	Cesium-137	Barium-140
Chattanooga	Jan	1.6	<5	19	24	26	<5
	Feb	1.4	<5	21	< 8	19	<5
	Mar	1.4	<5	24	10	21	<5
Clinton	Jan	1.4	<5	17	51	35	7
	Feb	1.2	<5	24	15	33	<5
	Mar	1.3	<5	23	12	25	<5
Knoxville	Jan	1.6	<5	16	9	22	7
	Feb	1.5	<5	15	10	15	<5
	Mar	1.4	<5	18	14	19	<5

4. Texas Milk Network January–March 1967

Texas State Department of Health [2]

The Texas State Department of Health initiated a statewide milk sampling network for radionuclide content in April 1964. At present, monthly samples of raw milk are collected from each of seven "active" sampling points. In addition, six "standby" stations have been supplied sample containers and shipping instructions and can be activated immediately if needed. The "active" and "standby" station locations, shown in figure 4 were chosen to give maximum geographical and population coverage.

Samples are routinely analyzed for strontium–89 and strontium–90 by a chemical separation technique employing ion exchange columns (*4*). Prepared samples are counted for 100 minutes in a low-background beta-particle counter.

Potassium–40, iodine–131, barium–140 and cesium–137 concentrations are determined by gamma-ray scintillation spectrometry. The procedure employs a 4- by 4-inch sodium iodide crystal and a 400-channel analyzer. Samples are counted for 100 minutes in a 3½ liter Marinelli beaker. The matrix method of calculation is used and detection limits at the 95-percent confidence level are 10 pCi/liter.

Results

Potassium–40, strontium–90, iodine–131, and cesium–137 results by station and month for January through March 1967 are presented in table 5. During this time, the strontium–89 and barium–140 concentrations were below their limits of detectability (5 and 10 pCi/liter, respectively). A summary of radionuclide concentrations in Texas milk is presented graphically in figure 5 for the period from April 1964 through March 1967.

Comparison of the observed radionuclide concentrations with the Federal Radiation Council guides for peacetime operations indicates that at no time during the period of surveillance did the radionuclide concentrations in Texas milk approach levels suggesting any remedial action (*5*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	January 1967
October–December 1966 and annual summary 1966	April 1967

[2] Acknowledgement is accorded to the staff of the Radiation Control Program, Division of Occupational Health and Radiation Control, under the direction of Mr. Martin C. Wukasch, chief engineer.

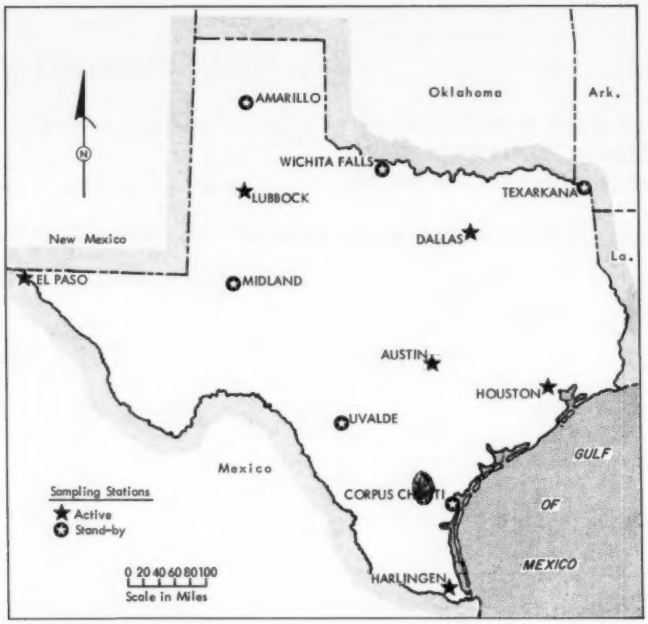

Figure 4. Texas milk sampling stations

Table 5. Radionuclide concentrations in Texas milk network, January–March 1967

Sampling location	Potassium-40 (pCi/liter)			Strontium-90 (pCi/liter)			Iodine-131 (pCi/liter)			Cesium-137 (pCi/liter)		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Austin	1,300	1,280	1,250	6	5	4	40	ND	ND	10	10	5
Fort Worth	1,260	1,310	1,260	6	7	6	ND	ND	ND	10	15	10
El Paso	1,230	1,310	1,410	4	4	2	ND	ND	ND	10	10	10
Harlingten	1,320	1,360	1,360	3	3	3	30	ND	ND	10	5	5
Houston	1,240	1,320	1,320	14	13	8	10	ND	ND	15	15	15
Lubbock	1,350	1,250	1,320	8	5	5	ND	ND	ND	10	10	5
San Antonio	1,270	1,420	1,300	5	7	4	ND	ND	ND	10	10	5
Average	1,280	1,320	1,310	7	6	5	12	ND	ND	11	11	8

ND, non-detectable.

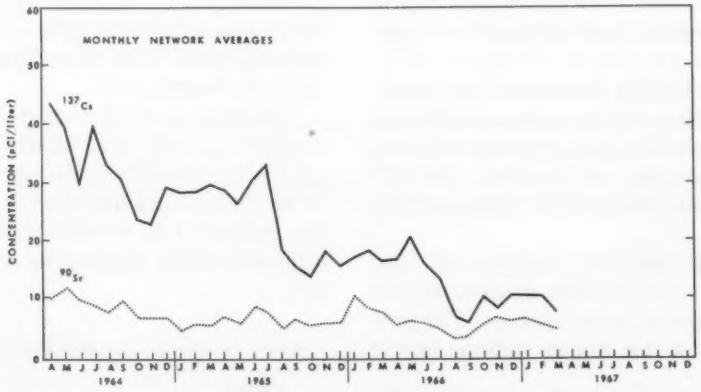

Figure 5. Radionuclide concentrations in Texas milk, January–March 1967

REFERENCES

(1) COLORADO STATE DEPARTMENT OF PUBLIC HEALTH, OCCUPATIONAL AND RADIOLOGICAL HEALTH DIVISION. Colorado milk network, October–December 1964 and summary 1962–1964. Radiol Health Data 6:202–204 (April 1965).

(2) PORTER, C. R., and M. W. CARTER. Field method for rapid collection of iodine-131 from milk. Public Health Rep 80:453–456 (May 1965).

(3) OKLAHOMA STATE DEPARTMENT OF HEALTH. Oklahoma milk network, March–July 1965. Radiol Health Data 6:540–541 (October 1965).

(4) PORTER, C., and B. KAHN. Improved determination of strontium-90 in milk by ion exchange method. Anal Chem 36:676–678 (March 1964).

(5) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Food and Diet Surveillance Activities

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuous basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Periodically, results from the United Kingdom Diet Survey, conducted by the United Kingdom Agricultural Research Council Radiobiological Laboratory, are presented for comparison with data observed in the United States. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Last presented
California Diet	May–August 1966	May 1967
Connecticut Standard Diet	July–December 1966	May 1967
Teenage Diet, FDA	February–November 1965	August 1966
Tri-City Diet, HASL	May–June 1966	June 1967
United Kingdom Diet	Annual summary 1965	December 1966

1. Radionuclides in Institutional Diet Samples October–December 1966

National Center for Radiological Health
Public Health Service

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiation surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Diet Sampling Program in 1961. This program is administered by the National Center for Radiological Health with the assistance of the National Center for Urban and Industrial Health (*1*).

The program was designed to provide estimates of the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially, the program was conducted at eight institutions; as of January 1965, its scope had increased to boarding schools or institutions in 50 municipalities. These institutions ranged from financially well-to-do boarding schools to orphanages with severe economic limitations.

Subsequent experience with the diets of school children of various ages indicated that the number of institutions sampled could be selectively reduced. As of July 1965, 21 institutions, distributed geographically as shown in figure 1, were being sampled. Previous results showed that the daily intake of teenage girls and children from 9 to 12 years of age were comparable while teenage boys consumed 20 percent more food per day (*1,2*). Consequently, estimates for teenage boys and/or girls can be calculated on the basis of the dietary intakes of children.

In general, the sampling procedure is the same at each institution. Each sample supplied monthly by each institution represents the edible portion of the diet for a full 7-day week (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Drink-

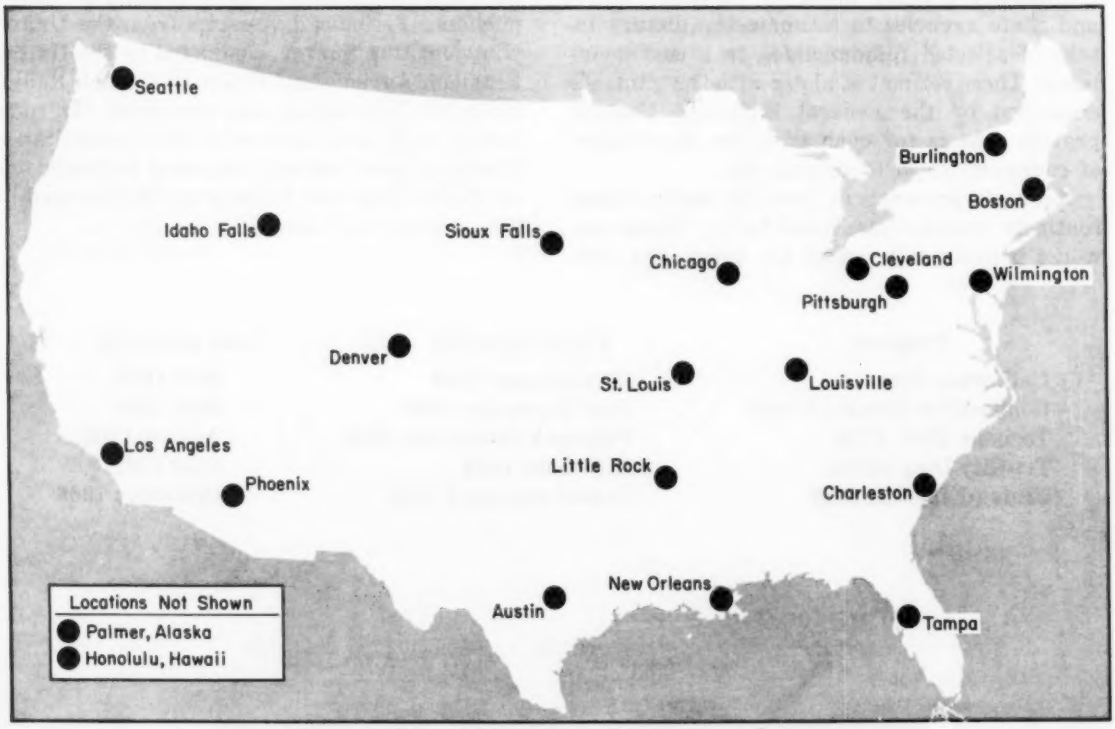

Figure 1. Current Institutional diet sampling locations

ing water, not included in the samples, is also sampled periodically. Each daily sample is kept frozen until the end of the collection period, and is then packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nev.; the Southeastern Radiological Health Laboratory, Montgomery, Ala.; or the Northeastern Radiological Health Laboratory, Winchester, Mass. A detailed description of sampling and

Table 1. Stable element and radionuclide concentration in institutional total diets of children, October–December 1966

Location of institution	Month 1966	Stable element (g/kg of diet)		Radionuclide concentration (pCi/kg of diet)			
		Calcium	Potassium	^{89}Sr	^{90}Sr	^{137}Cs	^{226}Ra
Alaska: Palmer	Oct	0.5	1.2	< 5	11	45	0.9
	Nov	1.0	1.6	< 5	71	65	1.8
	Dec	.6	1.6	< 5	8	40	.3
Ariz: Phoenix	Oct	.6	1.0	< 5	9	15	1.5
	Nov	.5	1.1	< 5	7	15	1.3
	Dec	.6	1.5	< 5	5	10	.4
Ark: Little Rock	Oct	.6	1.8	NA	13	15	1.1
	Nov	.5	1.5	NA	11	15	NA
	Dec	.5	1.5	NA	15	10	.9
Calif: Los Angeles	Oct	.8	1.8	< 5	6	25	2.2
	Nov	1.1	1.4	< 5	6	30	.9
	Dec	.6	1.2	< 5	6	20	1.0
Colo: Denver	Oct	.8	1.4	< 5	7	15	1.3
	Nov	.7	1.2	< 5	9	5	1.1
	Dec	.8	1.4	< 5	6	10	1.1
Del: Wilmington	Oct	.6	1.8	< 5	10	25	.7
	Nov	.8	1.8	< 5	11	25	.8
	Dec	.7	1.5	< 5	8	25	.6
Fla: Tampa	Oct	.6	1.5	NA	10	105	1.2
	Nov	.5	1.6	NA	10	45	NA
	Dec	.6	1.8	NA	10	50	1.7
Hawaii: Honolulu	Oct	.4	1.1	< 5	4	20	.6
	Nov	.4	1.1	< 5	6	25	.6
	Dec	.5	1.2	< 5	4	35	.9
Idaho: Idaho Falls	Oct	1.0	1.8	< 5	12	30	.6
	Nov	.9	1.7	< 5	9	30	.7
	Dec	.9	1.7	< 5	13	20	.5
Ill: Chicago	Oct	.6	1.4	< 5	7	25	.8
	Nov	.7	1.7	< 5	7	25	.8
	Dec	.7	1.6	< 5	8	25	.9
Ky: Louisville	Oct	.6	1.4	NA	8	15	1.5
	Nov	.8	1.6	NA	11	20	NA
	Dec	.8	1.6	NA	10	15	1.8
La: New Orleans	Oct	.7	1.7	< 5	17	25	.8
	Nov	.6	1.7	< 5	17	20	NA
	Dec	.4	1.5	10	9	10	1.0
Mass: Boston	Oct	.7	1.8	< 5	11	25	.7
	Nov	.6	1.9	< 5	10	25	.6
	Dec	.8	1.8	< 5	11	30	.7
Mo: St. Louis	Oct	NS	NS	NS	NS	NS	NS
	Nov	.9	1.7	< 5	11	20	.5
	Dec	.8	1.8	< 5	8	10	.5
Ohio: Cleveland	Oct	.7	1.7	< 5	7	20	.5
	Nov	.6	1.9	< 5	7	25	.6
	Dec	.6	1.8	< 5	8	15	.7
Pa: Pittsburgh	Oct	.5	1.4	< 5	9	25	.9
	Nov	.6	1.4	< 5	10	25	.6
	Dec	.6	1.3	< 5	9	20	.5
S. C: Charleston	Oct	.5	1.1	< 5	16	25	1.7
	Nov	.6	1.4	< 5	11	30	NA
	Dec	.7	1.4	< 5	14	25	1.2
S. Dak: Sioux Falls	Oct	NS	NS	NS	NS	NS	NS
	Nov *	.4	1.4	< 5	6	25	.7
	Dec	.6	1.6	< 5	5	15	.7
Tex: Austin	Oct	.6	1.4	NA	7	15	1.1
	Nov	.4	1.1	NA	7	5	NA
	Dec	.5	1.2	NA	7	15	1.0
Vt: Burlington	Oct	.6	1.8	< 5	12	30	.9
	Nov	.6	2.0	< 5	12	40	.5
	Dec	.8	1.6	< 5	10	30	1.0
Wash: Seattle	Oct	1.2	1.2	< 5	18	5	1.0
	Nov	1.2	1.4	< 5	16	45	1.1
	Dec	.6	1.8	< 5	7	40	.4
Institutional average	Oct	0.7	1.5	< 5	10	25	1.1
	Nov	0.7	1.5	< 5	13	25	0.8
	Dec	0.7	1.5	< 5	9	20	0.8

* Since milk component of the diet was not sent to the laboratory, concentrations are based only on solid and other liquid components of the diet.
NA, no analysis.
NS, no sample.

Note: Since iodine-131 and barium-140 concentrations were not detectable at most stations during the fourth quarter 1966, no provision was made for these nuclides in the table. The few exceptions are as follows:

October 1966, 10 pCi/kg of iodine-131 was reported for Louisville, Ky.

December 1966, 10 pCi/kg of iodine-131 was reported for Phoenix, Ariz.; Palmer, Alaska; Tampa, Fla.; and New Orleans, La.

December 1966, barium-140 was reported in the following institutions: Palmer, Alaska, 13 pCi/kg; Long Beach, Calif., 16 pCi/kg; and Austin, Tex., 12 pCi/kg.

Table 2. Intake of stable elements and radionuclides in institutional total diet for children (9 to 12 years of age), October–December 1966

Location of institution	Month 1966	Total weight (kg/day)	Stable element intake (g/day)		Radionuclide intake (pCi/day)			
			Calcium	Potassium	^{89}Sr	^{90}Sr	^{137}Cs	^{226}Ra
Alaska: Palmer	Oct	1.78	0.9	2.1	5	20	80	1.6
	Nov	1.14	1.1	1.8	5	81	75	2.0
	Dec	1.59	1.0	2.5	5	13	65	0.5
Ariz: Phoenix	Oct	2.22	1.3	2.2	5	20	35	3.3
	Nov	2.03	1.0	2.2	5	15	30	2.6
	Dec	1.61	1.0	2.4	5	8	15	.6
Ark: Little Rock	Oct	1.12	.7	2.0	NA	15	15	1.2
	Nov	1.14	.6	1.7	NA	13	15	NA
	Dec	1.15	.6	1.7	NA	17	10	1.0
Calif: Los Angeles	Oct	1.89	1.5	3.4	5	11	45	4.2
	Nov	2.10	2.3	2.9	5	13	65	1.9
	Dec	2.01	1.2	2.4	5	12	10	2.0
Colo: Denver	Oct	2.18	1.7	3.1	5	15	35	2.8
	Nov [a]	1.80	1.3	2.2	5	16	10	2.0
	Dec	2.08	1.7	2.9	5	12	20	2.3
Del: Wilmington	Oct	2.10	1.3	3.8	5	21	55	1.5
	Nov	1.91	1.5	3.4	5	21	50	1.5
	Dec	1.96	1.4	2.9	5	16	50	1.2
Fla: Tampa	Oct	2.25	1.4	3.4	NA	22	235	2.7
	Nov [b]	2.12	1.1	3.4	NA	21	95	NA
	Dec	2.03	1.2	3.7	NA	20	100	3.5
Hawaii: Honolulu	Oct [a]	1.96	.8	2.2	5	8	40	1.2
	Nov	1.93	.8	2.1	5	12	50	1.2
	Dec	2.04	1.0	1.2	5	8	70	1.8
Idaho: Idaho Falls	Oct [c]	1.96	2.0	3.5	5	24	60	1.2
	Nov [c]	2.23	2.0	3.8	5	20	65	1.6
	Dec [c]	2.21	2.0	3.8	5	29	45	1.1
Ill: Chicago	Oct	1.51	.9	2.1	5	11	40	1.2
	Nov [c]	1.77	1.2	3.0	5	12	45	1.4
	Dec	1.17	.8	1.9	5	9	30	1.1
Ky: Louisville	Oct [c]	1.44	.9	2.0	NA	12	20	2.2
	Nov [c]	1.82	1.5	2.9	NA	20	35	NA
	Dec [c]	1.96	1.6	3.1	NA	20	30	3.5
La: New Orleans	Oct	1.53	1.1	2.6	5	26	40	1.2
	Nov [b]	1.41	.8	2.4	5	24	30	NA
	Dec [b]	1.34	.5	2.0	15	12	15	1.3
Mass: Boston	Oct	1.50	1.0	2.7	5	16	35	1.0
	Nov	1.67	1.0	3.2	5	17	40	1.0
	Dec	1.54	1.2	2.8	5	17	45	1.1
Mo: St. Louis	Oct	NS	NS	NS	NS	NS	NS	NS
	Nov [c]	1.84	1.7	3.1	5	20	35	.9
	Dec [c]	1.54	1.2	2.8	5	12	15	.8
Ohio: Cleveland	Oct	1.20	.8	2.0	5	8	25	.6
	Nov [b]	1.08	.6	2.1	5	8	30	.6
	Dec	1.06	.6	1.9	5	8	15	.7
Pa: Pittsburgh	Oct	2.17	1.1	3.0	5	20	55	2.0
	Nov	2.11	1.3	3.0	5	21	55	1.3
	Dec	2.14	1.3	2.8	5	19	45	1.1
S. C: Charleston	Oct	1.57	.8	1.7	5	25	40	2.7
	Nov	1.49	.9	2.1	5	16	45	NA
	Dec	2.03	1.4	2.8	5	28	50	2.4
S. Dak: Sioux Falls	Oct	NS	NS	NS	NS	NS	NS	NS
	Nov	[d]						
	Dec	1.24	.7	2.0	5	6	20	.9
Tex: Austin	Oct	1.58	.9	2.2	NA	11	25	1.7
	Nov	1.48	.6	1.6	NA	10	5	NA
	Dec	1.72	.9	2.1	NA	12	25	1.7
Vt: Burlington	Oct	1.25	.8	2.2	5	15	40	1.1
	Nov	1.42	.9	2.8	5	17	55	.7
	Dec [c]	1.32	1.1	2.1	5	13	40	1.3
Wash: Seattle	Oct [c]	1.84	2.2	2.2	5	33	10	1.8
	Nov [c]	1.93	2.3	2.7	5	31	85	2.1
	Dec [c]	1.43	.9	2.6	5	10	55	.6
Institutional average	Oct	1.72	1.1	2.6	5	17	55	1.9
	Nov	1.62	1.0	2.4	5	20	45	1.4
	Dec	1.69	1.1	2.4	5	14	40	1.5

[a] Since food samples were collected from two or more children whose ages were unknown, data for this month were not used in the institutional average.
[b] Since food samples were collected from two or more children who were less than 9 years of age, data for this month were not used in the institutional average.
[c] Since food samples were collected from two or more children who were over 12 years of age, data for this month were not used in the institutional average.
[d] Total weight of sample is unknown since milk component of diet for Sioux Falls was not sent to laboratory. Intake values consequently could not be computed for this institution.
NA, no analysis.
NS, no sample.

analytical procedures was presented elsewhere (*3*).

Results

Table 1 presents the analytical results for institutional diet samples collected from October through December 1966, for children 9 to 12 years of age. The stable elements, calcium and potassium, are reported in g/kg of diet,

and the radionuclide concentrations of strontium–89, strontium–90, cesium–137, and radium–226 are expressed as pCi/kg of diet. The reported radionuclide concentrations of these samples are corrected for radioactive decay to the midpoint of the sample collection period, where applicable.

Dietary intakes, presented in table 2, were obtained by multiplying the food consumption rate in kg/day by the concentration values given in table 1. For the purpose of obtaining dietary intakes, "less than" 5 pCi/kg of strontium–89 was interpreted as 2.5 pCi/kg. The average food consumption rate during this period was 1.68 kg/day compared to the network average of 1.90 kg/day observed from 1961 through 1964 (*4*).

Strontium–90 dietary intake during this period averaged 17 pCi/day. This result falls within Range I as defined by the Federal Radiation Council (*5*). Cesium–137 intakes averaged 47 pCi/day during this period. Strontium–89, barium–140, and iodine–131 concentrations were generally below detectable levels.

REFERENCES

(*1*) ANDERSON, E. C., and D. J. NELSON, JR. Surveillance for radiological contamination in foods. Amer J Public Health 52:1391–1400 (September 1962).

(*2*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January–March 1965. Radiol Health Data 6:548–554 (October 1965).

(*3*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, April–June 1965. Radiol Health Data 7:92–98 (February 1966).

(*4*) GRUNDY, R. D., C. CALVERT, and A. G. BERGER. Summary of results of Institutional Total Diet Sampling Network, 1961–1964. Radiol Health Data 6:691–698 (December 1965).

(*5*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
1965 Annual Averages	July 1966
January–March 1966	October 1966
April–June 1966	January 1967
July–September 1966	April 1967

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclides intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These Standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be higher if total intake of radioactivity from all sources indicates that such intakes are within the guides recommended by FRC for control action. In the known absence [1] of strontium–90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when more complete analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the safe limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water programs previously reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium–90, respectively.

Program	Period reported	Last presented
California Water Sampling	January–June 1966	June 1967
Coast Guard Water Sampling	1965	November 1966
Colorado River Basin Sampling Network	1962–1964	November 1965
Drinking Water Analysis	1962	October 1965
Florida Water Sampling	1964	November 1965
Kentucky Water Sampling	May 1963–June 1964	March 1965
Lower Columbia River Radiological Survey in Oregon	August 1963–July 1964	October 1965
Minnesota Surface Water Sampling	January–June 1966	January 1967
New York Surface Water Sampling	June–December 1965	June 1966
North Carolina Water Sampling	1964	November 1965
Radiostrontium in Tap Water	March–November 1966	June 1967
Washington Surface Water Sampling	July 1964–June 1965	May 1966

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity in Surface Waters of the United States, January 1967

Division of Pollution Surveillance Federal Water Pollution Control Administration Department of Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Table 1 presents the current preliminary results of the alpha- and beta-particle analyses. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium–90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the June 1966 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioacivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or suspended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly

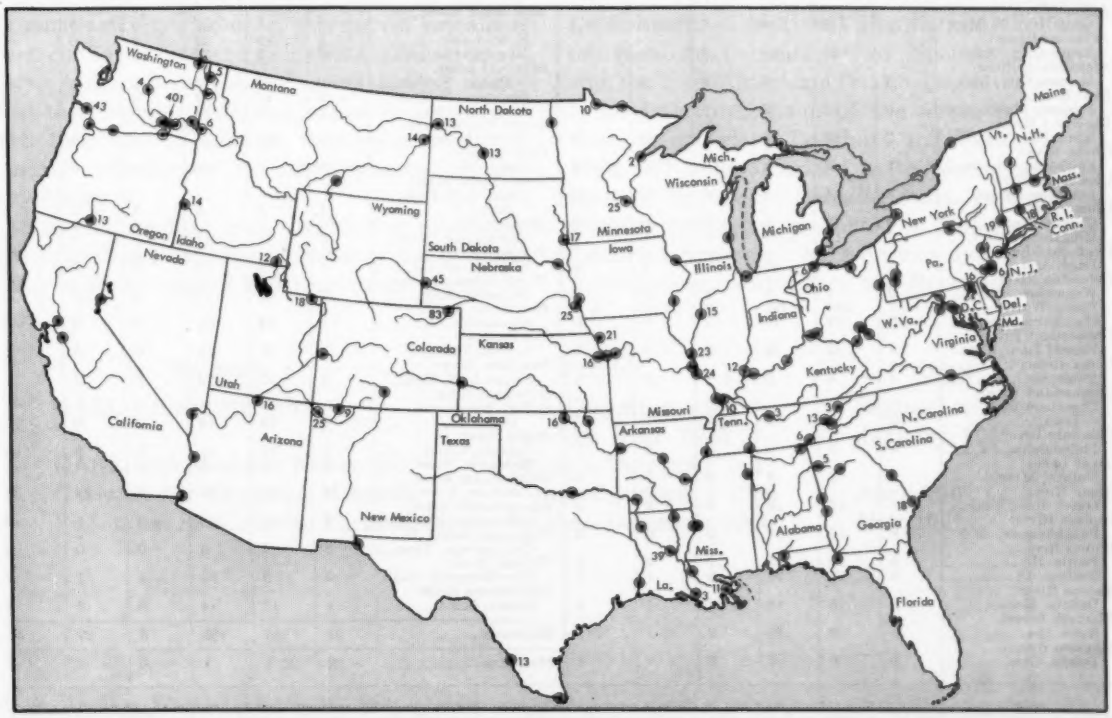

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, January 1967

average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During both December 1966 and January 1967, the following stations showed alpha radioactivity in excess of 15 pCi/liter on dissolved or suspended solids:

Atchafalaya River; Morgan City, La;
North Platte River; Henry, Nebr;
South Platte River; Julesburg, Colo.

During January, at Cedar Hill, N. Mex., on the Animas River, alpha radioactivity dropped to less than 15 pCi/liter on suspended solids. Pasco, Wash., on the Columbia River continued to show beta radioactivity on dissolved solids in excess of 150 pCi/liter.

REFERENCES

(1) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS Publication No. 663, 1958 edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(2) *Ibid.*, 1959 Edition.
(3) *Ibid.*, 1960 Edition.
(4) *Ibid.*, 1961 Edition.
(5) *Ibid.*, 1962 Edition.
(6) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Table 1. Radioactivity in raw surface waters, January 1967

Station	Average beta radioactivity (pCi/liter)			Average alpha radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex.	1	8	9	0	1	1
Arkansas River:						
Ponca City, Okla.	1	15	16	0	4	4
Atchafalaya River:						
Morgan City, La.	3	< 1	3	16	9	25
Bear River:						
Preston, Idaho	0	12	12	0	3	3
Big Sioux River:						
Sioux Falls, S. Dak.	2	15	17	< 1	2	2
Chena River:						
Fairbanks, Alaska	1	2	3	0	0	0
Clearwater River:						
Lewiston, Idaho	2	4	6	0	0	0
Clinch River:						
Clinton, Tenn.	0	3	3	0	0	0
Kingston, Tenn.*	2	11	13	0	1	1
Colorado River:						
Page, Ariz.	1	15	16	0	4	4
Columbia River:						
Wenatchee, Wash.	0	4	4	0	0	0
Pasco, Wash.*	37	364	401	0	< 1	< 1
Clatskanie, Ore.	10	33	43	0	0	0
Connecticut River:						
Enfield Dam, Conn.	6	12	18	0	0	0
Coosa River:						
Rome, Ga.	2	3	5	< 1	0	< 1
Cumberland River:						
Cheatham Lock, Tenn.	0	3	3	0	0	0
Delaware River:						
Philadelphia, Pa.	1	5	6	0	0	0
Great Lakes:						
Duluth, Minn.	0	2	2	0	0	0
Green River:						
Dutch John, Utah	1	17	18	0	3	3
Hudson River:						
Poughkeepsie, N.Y.	6	13	19	0	0	0
Illinois River:						
Peoria, Ill.	5	10	15	1	2	3
Grafton, Ill.	0	23	23	0	1	1
Kansas River:						
DeSoto, Kans.	1	15	16	0	1	1
Klamath River:						
Keno, Ore.	5	8	13	0	< 1	< 1
Maumee River:						
Toledo, Ohio	1	5	6	0	1	1
Mississippi River:						
St. Paul, Minn.	6	19	25	0	0	0
E. St. Louis, Ill.	5	19	24	0	0	0
New Orleans, La.	3	8	11	1	1	2
Missouri River:						
Williston, N. Dak.	0	13	13	0	3	3
Bismarck, N. Dak.	< 1	13	13	0	3	3
St. Joseph, Mo.	2	19	21	0	4	4
North Platte River:						
Henry, Nebr.	2	43	45	0	26	26
Ohio River:						
Cairo, Ill.	3	7	10	1	0	1
Pend Oreille River:						
Albeni Falls Dam, Idaho	1	4	5	0	< 1	< 1
Platte River:						
Plattsmouth, Nebr.	3	22	25	1	6	7
Potomac River:						
Washington, D.C.	1	5	6	0	0	0
Rainy River:						
Baudette, Minn.	0	10	10	0	0	0
Red River, South:						
Alexandria, La.	11	28	39	0	0	0
Rio Grande:						
Laredo, Tex.	1	12	13	0	5	5
San Juan River:						
Shiprock, N. Mex.	8	17	25	2	7	9
Savannah River:						
Port Wentworth, Ga.*	8	10	18	1	0	1
Snake River:						
Payette, Idaho	2	12	14	0	6	6
Wawawai, Wash.	0	1	1	0	1	1
South Platte River:						
Julesburg, Colo.	23	60	83	4	29	33
Susquehanna River:						
Conowingo, Md.	6	10	16	0	0	0
Tennessee River:						
Chattanooga, Tenn.	3	3	6	0	0	0
Wabash River:						
New Harmony, Ind.	3	9	12	1	1	2
Yellowstone River:						
Sidney, Mont.	1	13	14	0	5	5
Maximum	37	364	401	16	29	33
Minimum	0	< 1	1	0	0	0

* Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides common to all stations.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product activity. To date, this surveillance has been confined chiefly to gross beta-particle analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
HASL Fallout Network	July–December 1965	September 1966
	Calendar year 1965	January 1967
HASL 80th Meridan Network	October–December and	
National Air Sampling Network	annual summary 1966	April 1967
Plutonium in Airborne Particulates	October–December 1966	May 1967

1. Radiation Surveillance Network March 1967

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) which regularly gathers samples at 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Daily samples of airborne particulates and precipitation are forwarded to the Radiation Surveillance Network Laboratory in Rockville, Md., for laboratory analysis. The alerting function of the network is provided by routine field estimates of the gross beta radioactivity made by the station operators after decay of radon and thoron daughter products prior to submission of the samples for laboratory analysis. When high air levels are reported, appropriate officials are promptly notified. Compilation of field estimates and laboratory confirmations are reported elsewhere on a monthly basis (*1*). A detailed description of the sampling and analytical procedures was presented in the November 1966 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air and deposition by precipitation during March 1967. Time profiles of gross beta radioactivity in air for eight RSN stations are shown in figure 2.

Gross beta radioactivity in air and precipitation decreased to near normal levels during March.

Figure 1. Radiation Surveillance Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, March 1967

Station location		Number of samples		Air surveillance, gross beta radioactivity (pCi/m³)			Last profile in *RHD&R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average [a]		Total depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	31	4	0.36	0.04	0.16	Nov 66	43	< 9
Alaska:	Adak	31	----------	.29	.00	.11	Jun 67	[b]	
	Anchorage	19	4	.40	.03	.18	Dec 66	9	< 2
	Attu Island	17	----------	.13	.01	.05	Jul 67	[b]	
	Fairbanks	[c]	----------	----------	----------	----------	Jan 67	[b]	
	Juneau	21	6	.18	.01	.09	Apr 67	187	<37
	Kodiak	8	----------	.34	.03	.13	May 67	[b]	
	Nome	[c]	----------	----------	----------	----------	Sep 66	[b]	
	Pt. Barrow	26	----------	.14	.05	.10	Aug 66	[b]	
	St. Paul Island	[c]	----------	----------	----------	----------	Oct 66	[b]	
Ariz:	Phoenix	31	----------	.63	.11	.29	Apr 67	[b]	
Ark:	Little Rock	30	4	.41	.03	.15	Dec 66	76	<15
Calif:	Berkeley	23	9	.31	.02	.15	May 67	140	<28
	Los Angeles	23	4	.41	.05	.18	Sep 66	59	<12
C. Z:	Ancon	18	----------	.08	.01	.05	May 67	[b]	
Colo:	Denver	31	2	.37	.10	.21	May 67	17	< 3
Conn:	Hartford	31	10	.40	.04	.17	Apr 67	93	<19
Del:	Dover	22	----------	.30	.01	.14	Nov 66	[b]	
D. C:	Washington	27	8	.34	.01	.12	Aug 66	107	<22
Fla:	Jacksonville	30	2	.39	.03	.15	Dec 66	17	< 3
	Miami	30	4	.36	.04	.15	Apr 67	113	<23
Ga:	Atlanta	31	6	.43	.04	.19	Oct 66	58	<12
Guam:	Agana	31	----------	.11	.00	.04	Nov 66	[b]	
Hawaii:	Honolulu	31	4	.33	.01	.09	Jul 67	168	<34
Idaho:	Boise	27	2	.45	.01	.17	Jul 67	10	< 2
Ill:	Springfield	27	4	.33	.02	.11	Aug 66	70	<14
Ind:	Indianapolis	30	7	.41	.03	.16	Oct 66	88	<18
Iowa:	Iowa City	31	6	.37	.03	.15	May 67	50	<10
Kans:	Topeka	31	4	.33	.08	.18	Dec 66	22	< 5
Ky:	Frankfort	21	6	.35	.03	.16	Aug 66	51	<10
La:	New Orleans	30	4	.40	.04	.18	Aug 66	31	< 6
Maine:	Augusta	30	7	.30	.05	.16	Sep 66	37	< 7
	Presque Isle	21	----------	.29	.07	.14	May 67	[b]	
Md:	Baltimore	22	6	.32	.01	.14	Apr 67	43	< 9
	Rockville	21	3	.31	.01	.13	Jul 67	99	<20
Mass:	Lawrence	30	5	.36	.03	.17	Nov 66	53	<11
	Winchester	19	6	.60	.02	.20	Jun 67	94	<19
Mich:	Lansing	30	----------	.35	.02	.16	Jul 67	[b]	
Minn:	Minneapolis	21	5	.21	.05	.12	Nov 66	21	< 4
Miss:	Jackson	30	3	.32	.03	.12	Sep 66	43	< 9
Mo:	Jefferson City	31	8	.34	.03	.14	Oct 66	41	< 8
Mont:	Helena	27	5	.35	.08	.16	Jun 67	39	< 8
Nebr:	Lincoln	22	1	.49	.03	.17	Oct 66	19	< 4
Nev:	Las Vegas	29	----------	1.01	.03	.36	Jan 67	[b]	
N. H:	Concord	20	----------	.32	.04	.18	Aug 66	[b]	
N. J:	Trenton	31	9	.37	.01	.12	Sep 66	34	< 7
N. Mex:	Santa Fe	28	3	.61	.04	.15	Jun 67	15	< 3
N. Y:	Albany	23	6	.32	.04	.16	Oct 66	46	< 9
	Buffalo	23	----------	.30	.04	.11	May 67	[b]	
	New York City	29	----------	.37	.01	.14	Jun 67	[b]	
N. C:	Gastonia	31	5	.41	.06	.19	May 67	61	<12
N. Dak:	Bismarck	31	4	.26	.04	.13	Aug 66	6	< 1
Ohio:	Cincinnati	20	----------	.32	.05	.18	Nov 66	[b]	
	Columbus	29	8	.44	.07	.20	Sep 66	99	<20
	Painesville	30	9	.29	.03	.15	Apr 67	41	< 9
Okla:	Oklahoma City	30	6	.19	.07	.12	Jul 67	47	<10
	Ponca City	27	3	.12	.03	.06	Apr 67	22	< 4
Ore:	Portland	30	23	.24	.02	.09	Oct 66	121	<24
Pa:	Harrisburg	30	2	.35	.02	.11	Oct 66	83	<17
P. R:	San Juan	25	2	.31	.03	.14	Sep 66	28	< 6
R. I:	Providence	28	6	.28	.03	.13	Jul 67	87	<18
S. C:	Columbia	26	4	.41	.05	.17	Jun 67	73	<15
S. Dak:	Pierre	31	----------	.31	.06	.15	Apr 67	[b]	
Tenn:	Nashville	31	4	.26	.04	.13	Jul 67	96	<19
Tex:	Austin	30	4	.30	.05	.16	Nov 66	22	< 4
	El Paso	31	2	.64	.05	.21	Aug 66	4	< 1
Utah:	Salt Lake City	31	5	.79	.11	.29	Sep 66	44	< 9
Vt:	Barre	29	6	.31	.06	.16	Dec 66	21	< 4
Va:	Richmond	31	8	.46	.03	.14	Dec 66	64	<13
Wash:	Seattle	30	15	.15	.02	.06	Dec 66	71	<14
	Spokane	31	5	.30	.05	.13	Nov 66	23	< 5
W. Va:	Charleston	31	10	.27	.02	.14	Jun 67	156	<31
Wis:	Madison	28	4	.22	.01	.11	Dec 66	44	< 9
Wyo:	Cheyenne	31	4	.29	.07	.17	Jan 67	15	< 3
Network summary		1,928	306	1.01	0.00	0.15	----------	59	<12

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of 0.005 or less are reported and used in averaging as 0.00 pCi/m³.

[b] No precipitation sample collected.

[c] No report received.

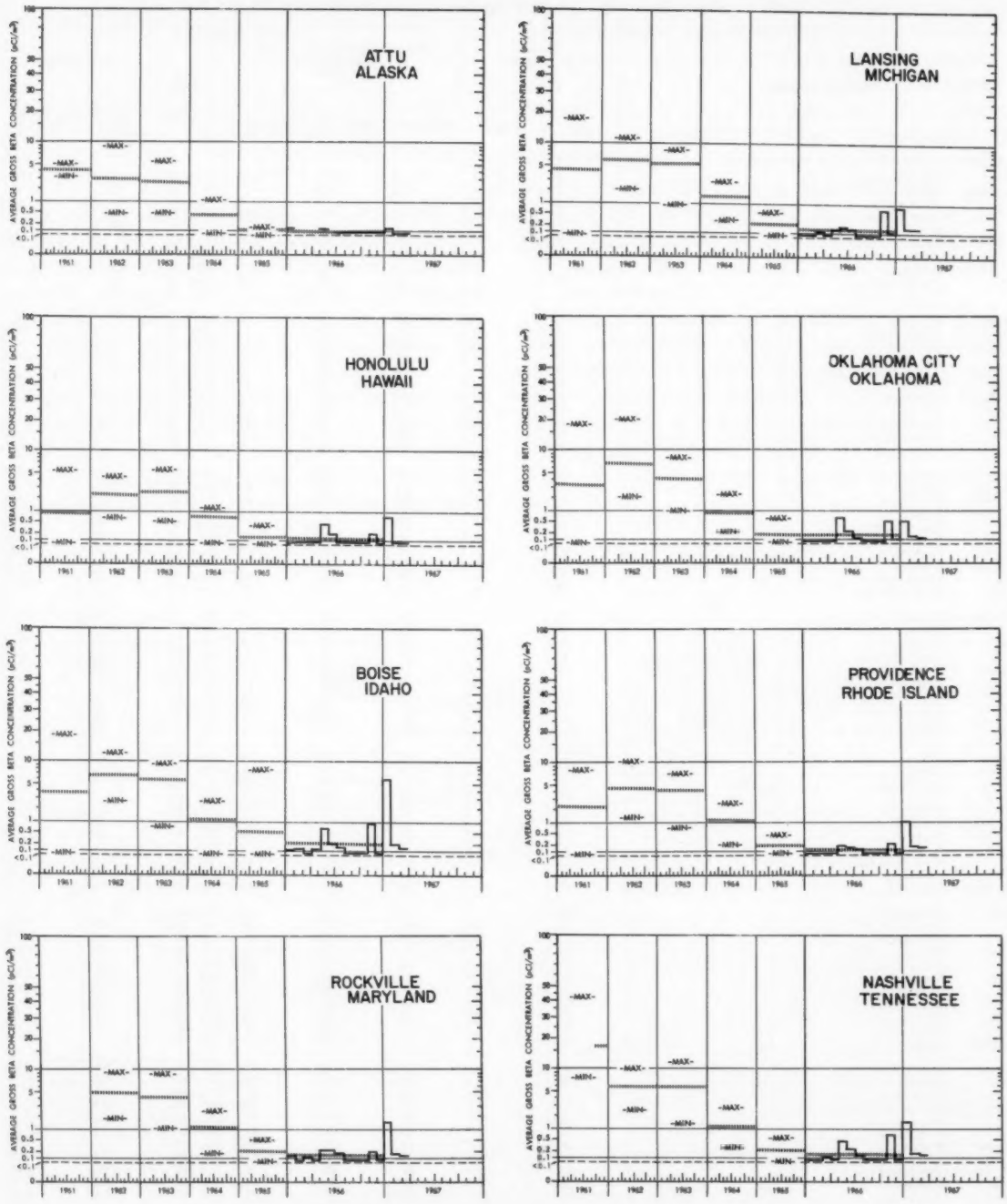

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Surveillance Network, 1961–March 1967

2. Canadian Air and Precipitation Monitoring Program, March 1967

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*2–6*).

A summary of the sampling procedures and methods of analysis was presented in the November 1966 issue of *Radiological Health Data and Reports.*

[1] Prepared from information and data in the April 1967 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for March 1967 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, March 1967

Station	Number of samples	Air surveillance radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	0.3	0.1	0.2	53	1.0
Coral Harbour	29	.2	.0	.1	11	.5
Edmonton	31	.3	.1	.2	15	.5
Ft. Churchill	31	.2	.1	.1	28	.5
Ft. William	31	.3	.1	.2	68	1.8
Fredericton	31	.4	.1	.2	79	3.7
Goose Bay	31	.2	.1	.1	60	1.0
Halifax	31	.3	.0	.2	10	1.3
Inuvik	30	.2	.1	.1	18	.4
Montreal	30	.5	.0	.2	76	4.4
Moosonee	31	.3	.1	.2	30	1.0
Ottawa	31	.4	.1	.2	318	8.0
Quebec	31	.3	.1	.2	83	2.4
Regina	23	.3	.1	.2	42	1.2
Resolute	31	.2	.0	.1	NS	NS
St. John's, Nfld.	31	.3	.0	.1	14	1.4
Saskatoon	30	.3	.0	.1	12	.5
Sault Ste. Marie	31	.3	.0	.2	74	2.5
Toronto	31	.4	.0	.2	32	.8
Vancouver	31	.2	.0	.1	9	.8
Whitehorse	31	.3	.0	.2	26	.5
Windsor	31	.4	.0	.2	57	1.5
Winnipeg	31	.3	.1	.2	48	.8
Yellowknife	31	.2	.1	.1	32	.4
Network summary	731	0.5	0.0	0.2	52	1.6

NS, no sample.

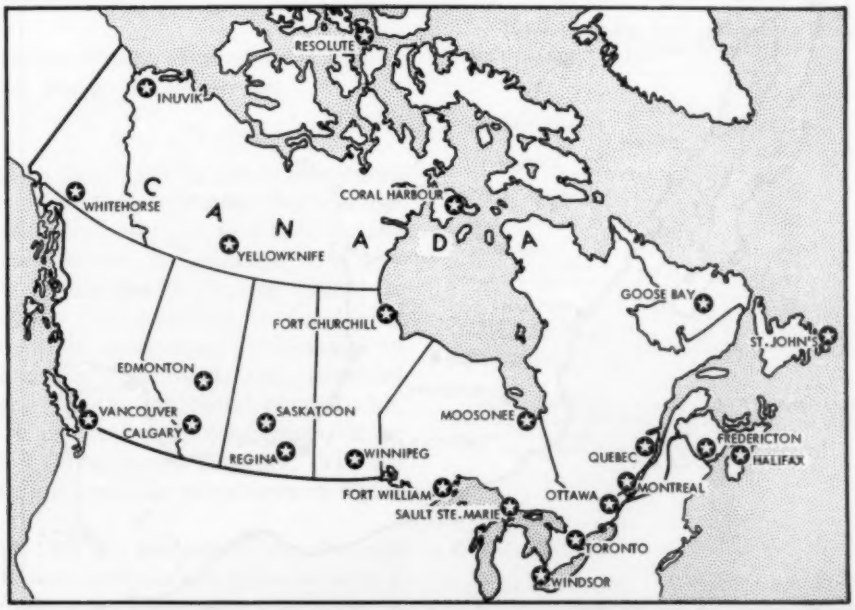

Figure 3. Canadian air and precipitation sampling stations

3. Mexican Air Monitoring Program March 1967

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high-volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of eight samples per month were needed to get a reliable average activity at each station (*7*).

The maximum, minimum, and average fission product beta concentrations in surface air during March 1967 are presented in table 3.

Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, March 1967

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	19	0.4	0.1	0.3
Chihuahua	15	1.1	<0.1	.4
Ciudad Juàrez	15	.6	.1	.3
Ensenada	5	.6	.1	.3
Guadalajara	3	.1	.1	.1
Guaymas	NS			
La Paz	7	.7	.1	.4
Matamoros	NS			
Mazatlàn	16	1.1	.1	.5
Mérida	9	.2	.1	.1
M*xico, D.F.	15	.3	<0.1	.1
Nuevo Laredo	8	.4	.1	.2
San Luis Potosi	NS			
Tampico	13	.2	.1	.1
Torreón	13	1.0	<0.1	.3
Veracrus	NS			

NS, no sample collected, station temporarily shutdown.

Figure 5. Pan American Air Sampling Program stations

4. Pan American Air Sampling Program March 1967

Pan American Health Organization and U.S. Public Health Service

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs. The sampling equipment and analytical services are provided by the National Center for Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network. The air sampling station positions are shown in figure 5.

The March 1967 air monitoring results from the participating countries are given in table 4. No fresh fission products were identified on PAHO air samples during March.

Table 4. Gross beta radioactivity in surface air PAHO, March 1967

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average *
Argentina: Buenos Aires	17	0.13	0.03	0.07
Bolivia: La Paz	NS			
Colombia: Bogota	25	.05	.02	.04
Chile: Santiago	22	.05	.00	.02
Ecuador: Guayaquil	26	.05	.01	.03
Jamaica: Kingston	17	.14	.04	.08
Peru: Lima	16	.05	.02	.03
Venezuela: Caracas	17	.11	.00	.06
West Indies: Trinidad	21	.09	.02	.06
Pan American summary	161	0.14	0.00	0.05

* The monthly average is calculated by weighting the individual samples with length of sampling period. Values of 0.005 pCi/m³ or less are reported and used in averaging as 0.00 pCi/m³

NS, indicates no report received.

REFERENCES

(*1*) RADIATION SURVEILLANCE NETWORK. Monthly tabulation of findings. National Center for Radiological Health, Public Health Service, Washington, D.C. 20201 (Distribution by official request).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).
(3) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).
(4) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).
(5) BEALE, J., and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).
(6) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).
(7) VASQUEZ, M., and R. M. De NULMAN. Estudios sobre la radioactividad ambiental en la República Mexicana, 1963–1965. Comisión Nacional de Energía Nuclear, Dirección General de Sequridad Radiológica (en prensa 1966).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium–90 in Human Bone, July–September 1966 [1]

National Center for Radiological Health
Public Health Service

To obtain data on the concentration of strontium–90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. The target population includes children and young adults up to 25 years of age. Since strontium–90 in measurable amounts has been present in the global environment for more than a decade and major calcium accretion ceases by age 17 or 18, persons over 25 years old are of limited interest in the program. This has been confirmed by analyses of selected samples of people in older age groups, the results having shown their bone strontium–90 content to be low and age-independent (*1*).

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age.

Most specimens received to date have been vertebrae and ribs. Efforts to collect long bones for comparison of results with British data have not been successful.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory of the National Center for Radiological Health, at Winchester, Mass. Sample collection and preparation are explained elsewhere (*2*). Strontium–90 is measured by TBP extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium–90 content is then calculated (*3*) from the yttrium–90 activity. For the purpose of maintaining analytical reproductibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples. To further check and maintain analytical accuracy, synthetic "bone ash" samples (calcium phosphate spiked with strontium–90) are analyzed periodically and cross-check analyses are carried out quarterly with the Health and Safety Laboratory of the AEC, which performs similar analyses.

[1] Period during which death or surgical procedure occurred.

The analytical results for strontium–90 in individual bones from persons dying during the third quarter (July–September) of 1966 along with other pertinent data (place of residence, sex, bone type, and cause of death), are presented in table 1 in order of increasing age within each geographical sampling region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium–90 per gram of ash (the primary determination), per gram of calcium (for comparison with other data and for purposes of model development), and per gram of bone (as a rough indication of dose). Two-sigma counting errors are reported for the ash concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–4*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
First quarter 1966	February 1967
Second quarter 1966	March 1967

REFERENCES

(*1*) RIVERA, J. Strontium–90 in human vertebrae, 1962–1963. Radiol Health Data 5:511–513 (October 1964).

(*2*) WEISS, E. S., W. H. LAND, K. H. FALTER and R. M. HALLISEY. Strontium–90 content of human bones, 1961–1963. Radiol Health Data 5:231–239 (May 1964).

(*3*) PUBLIC HEALTH SERVICE, NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY. Analysis of environmental samples, chemical and radiochemical procedures, NERHL 64–1 (April 1964).

(*4*) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and A. S. GOLDIN. Strontium–90 in human bone. Radiol Health Data 5:620–628 (December 1964).

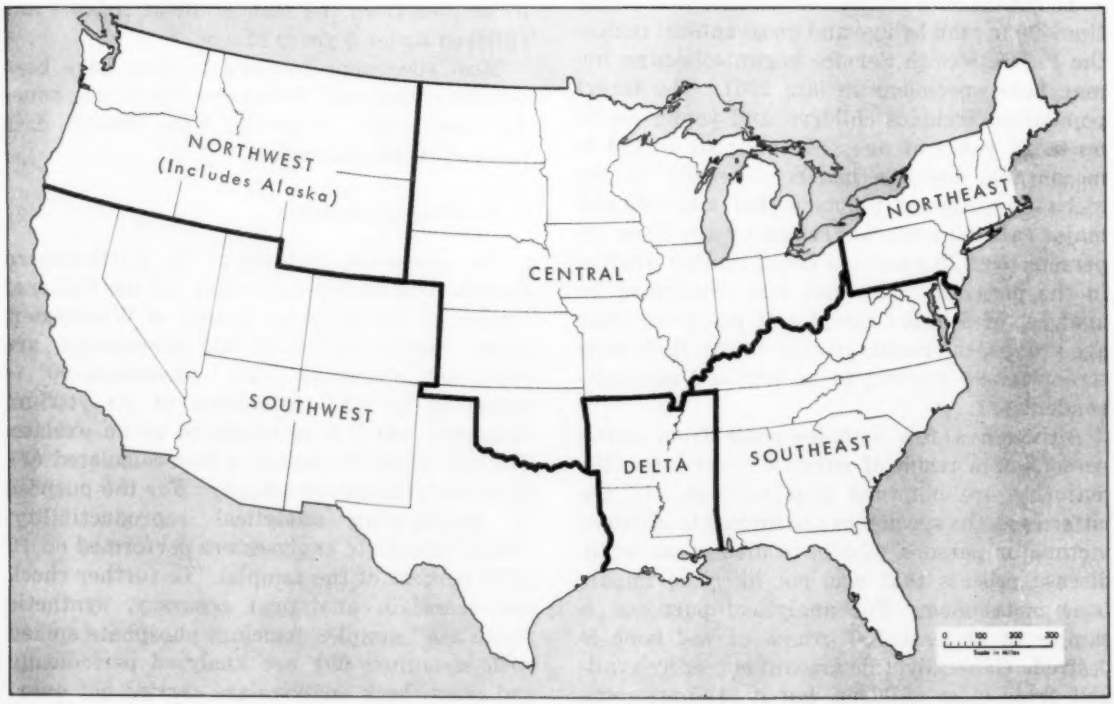

Figure 1. Geographical regions for the PHS Human Bone Sampling Network

Table 1. Strontium-90 in human bone, deaths and surgical procedures during July–September 1966

Sampling region and state of residence	Sex	Bone type [a]	Age at death [b] (years)	Cause of death	Strontium-90 pCi/g of:		
					Ash ±2σ error	Calcium	Bone
NORTHEAST:							
Mass.	M	V	2	Hydrocephalus	1.12 ±0.10	3.06	0.10
Mass.	F	V	3	Head injuries	1.51 ± .12	3.32	.12
Mass.	M	V	3	Meningococcemia	1.27 ± .15	3.65	.10
Vt.	M	V	5	Tetralogy of Fallot	1.35 ± .16	3.94	.11
Mass.	F	V	6	Acute leukemia	1.18 ± .18	3.30	.10
Pa.	F	V	8	Encephalitis	.77 ± .11	2.06	.07
N.Y.	M	V	8	Acute leukemia	.80 ± .11	2.32	.05
Mass.	F	V	8	Tracheobronchitis	.75 ± .14	2.18	.08
Mass.	F	V	9	Rheumatic heart disease	1.19 ± .10	3.28	.13
Pa.	M	V	9	Multiple injuries	.71 ± .06	1.95	.07
N.H.	F	V	10	Tetralogy of Fallot	1.24 ± .10	3.32	.13
Vt.	M	V	11	Degenerative brain disease	1.16 ± .12	3.19	.09
Maine	F	V	11	Aplastic anemia	.71 ± .06	1.85	.07
N.Y.	F	V	11	Subdural hematoma	.94 ± .09	2.46	.10
Mass.	F	V	12	Mitral regurgitation	.77 ± .07	2.06	.09
N.H.	M	V	12	Chronic renal disease	1.93 ± .11	5.28	.19
N.Y.	M	V	13	Carcinoma of testis	1.34 ± .09	3.63	.16
Mass.	M	V	14	Multiple injuries	1.03 ± .09	2.78	.12
Mass.	M	V	15	Lymphosarcoma	.91 ± .06	2.43	.11
Pa.	F	V	15	Death during surgery	1.49 ± .10	3.86	.22
N.Y.	M	V	16	Acute leukemia	.97 ± .07	2.58	.11
N. H.	M	V	16	Acute subdural hematoma	.90 ± .07	2.39	.12
N.Y.	M	V	17	Neuroblastoma	1.13 ± .10	3.01	.13
Mass.	M	V	18	Fracture of femur	.81 ± .09	2.11	.11
Mass.	F	V	18	Myelomeningocoele	.94 ± .09	2.55	.13
N.J.	F	V	18	Multiple injuries	.67 ± .06	1.74	.09
Pa.	M	V	19	Asphyxiation	.91 ± .12	2.37	.15
Vt.	M	V	19	Drowning	.97 ± .08	2.60	.12
Vt.	F	V	20	Gunshot wound of head	.80 ± .08	2.10	.11
Vt.	M	V	22	Traumatic hemothorax	.78 ± .08	2.12	.09
N.Y.	M	V	24	Carcinoma of testis	.74 ± .07	1.95	.10
Mass.	F	V	25	Coronary artery disease	1.11 ± .10	3.01	.13
CENTRAL:							
Wis.	F	V	1	Tricuspid atresia	1.51 ±0.18	4.33	.14
Wis.	F	V	2	Cardiac fibroelastosis	1.54 ± .21	4.42	.15
Wis.	F	V	2	Tetralogy of Fallot	1.58 ± .22	4.60	.12
Wis.	F	V	2	Acute leukemia	.88 ± .12	2.55	.08
Minn.	M	V	3	Ruptured liver and spleen	1.48 ± .11	4.01	.14
Ohio	M	V	3	Viral encephalitis	.65 ± .05	1.95	.05
Okla.	M	V	4	Acute leukemia	1.03 ± .11	2.91	.08
Wis.	M	V	4	Encephalitis	.31 ± .08	0.88	.03
Ohio	F	V	4	Vascular malformation	1.25 ± .11	3.38	.12
Wis.	M	V	4	Congenital heart disease	1.09 ± .14	3.05	.11
Wis.	F	V	5	Encephalitis	.89 ± .11	2.39	.08
Wis.	M	V	5	Glomerulonephritis	.54 ± .07	1.51	.05
Wis.	F	V	11	Death during surgery	.71 ± .09	2.03	.10
Ohio	M	V	16	Intracranial hemorrhage	1.11 ± .08	2.91	.15
Ohio	M	V	18	Traumatic hemothorax	.81 ± .06	2.16	.10
Wis.	M	V	19	Sickle cell anemia	.87 ± .11	2.33	.09
Mo.	M	S	20	Head injuries	.74 ± .13	3.06	.02
DELTA:							
Tex.	F	V	1	Bacterial meningitis	1.08 ±0.06	3.16	.09
La.	M	V	3	Acute leukemia	2.29 ± .21	6.51	.16
La.	F	V,R	3	Cor biloculare	3.61 ± .19	9.55	.41
La.	M	V	9	Lymphoblastic leukemia	1.03 ± .15	2.91	.08
([d])	F	V	12	([d])	1.35 ± .10	3.60	.17
La.	M	V	18	Guillain-Barré syndrome	1.39 ± .09	3.58	.19
La.	F	V	23	Glomerulonephritis	1.06 ± .10	2.77	.12
Tex.	F	V	25	Endometritis	.38 ± .06	1.01	.05
NORTHWEST:							
Wash.	M	V	13	Acute leukemia	0.93 ±0.09	2.46	.12
Ore.	M	V	15	([d])	.39 ± .05	1.03	.04
Alaska	M	R	16	([c])	1.69 ± .18	4.42	.46
Ore.	M	V	18	Head injury	.71 ± .07	1.87	.11
Ore.	M	V I, SK	19	Multiple injuries	.86 ± .07	2.24	.26
Ore.	F	V	20	Cervical spine injury	.65 ± .07	1.69	.08
Ore.	F	V	24	Diabetic acidosis	.69 ± .06	1.83	.08

[a] Type of bone:
R, rib
V, vertebrae
S, sternum
I, illium
SK, skull

[b] Age given as of last birthday prior to death.

[c] Sample obtained from surgical procedure.

[d] Information not yet available.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation protection standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual." [1]

Summaries of the environmental radioactivity data follow for the Paducah Plant, Pinellas Peninsula Plant, and the Shippingport Atomic Power Station.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Paducah Plant
July–December and Calendar Year 1966 [2]

Union Carbide Corporation
Paducah, Kentucky

The Paducah Plant is a Government-owned gaseous diffusion plant operated by the Nuclear Division of the Union Carbide Corporation for the Atomic Energy Commission. The diffusion plant processes large quantities of relatively pure uranium compounds. The uranium hexafluoride manufacturing plant (a former source of diffusion plant feed) was placed on standby in June of 1964. Parts of the associated uranium metal foundry are operated infrequently as the need arises; otherwise, it is also on a standby status. A decontamination and uranium recovery facility operates to prepare equipment for repair and to recover impure or scrap uranium materials. Depleted uranium metal is fabricated into shields, weights, ballasts, or other shapes on a nonroutine basis. The major sources of external penetrating radiation are the daughter products of uranium, thorium–234 and protactinium–234, which may be concentrated by uranium recovery processes or by uranium hexafluoride vaporization. The element uranium can be a physiological hazard only if allowed to enter the body. The chemical toxicity of the uranium processed at the Paducah Plant overshadows any probably biological effects of radiation from this element, thus making it comparable as a physiological hazard to lead, mercury, or other well-known heavy metals.

Because of the necessity for health protection in process areas, the high intrinsic value of uranium, and the desire to maintain a wholesome relationship with neighboring communities and individuals, the Paducah Plant provides confinement and recovery systems at the plant. The environmental monitoring program provides for continuously sampling the air at four stations around the plant perimeter fence, and at five stations located approximately 1 mile outside this fence (figure 1). Big Bayou Creek water is sampled continuously, and grab samples are collected at five locations in the Ohio River. In addition, gamma radiation readings are taken each month at each of the air sampling stations with a Geiger-Mueller type meter at a distance of 3 feet above ground level.

Basic standards

The radiation protection standards observed at the Paducah Plant for exposure to radiation and radioactive materials, both for the in-plant

[2] Summarized from "Environmental Concentrations of Radioactive Materials near the Paducah Plant—Report for the Year and Second Half of 1966."

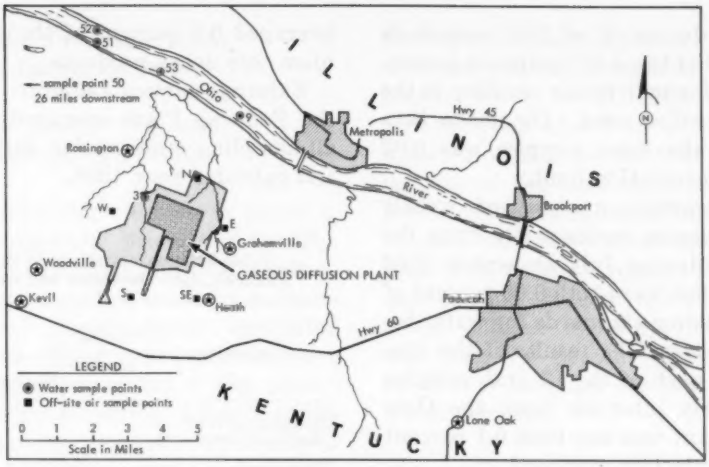

Figure 1. Sampling locations, Paducah Gaseous Diffusion Plant

work environment or employees and for offsite exposure of the general population, are those contained in Appendix 0524 of the AEC manual.

The standards specify that the radiation or radioactive materials outside a controlled area, and which have resulted from operations within that controlled area, shall be such that it is improbable that any individual may receive a dose of external radiation greater than 0.5 rem in any year, and that the average exposure of a suitable population sample may not exceed one-third of this dose. To meet this standard, the average concentration of radioisotopes in air or water beyond a controlled area should not exceed one-tenth of the maximum permitted for occupational exposure of 168 hours per week. For the purposes of such control, the concentrations of such radionuclides in air or water may be averaged over periods of time up to 1 year.

Discussion

Data summarizing the environmental concentrations of radioactive materials in air and water and the gamma radiation levels in the vicinity of the Paducah Gaseous Diffusion Plant are presented in tables 1 through 4.

Air samples were collected continuously at each of the four stations at the plant perimeter fence and at five stations about 1 mile outside the plant. Air is filtered at 0.3 cfm through 2-inch diameter membrane filters which are replaced weekly and counted for alpha and beta radioactivity.

The average alpha particle count—interpreted as uranium, the most likely source of radioactivity—of the 234 air samples collected during July–December 1966, and the 467 air

Table 1. Uranium concentrations in outdoor air samples Paducah, July–December and calendar year 1966

Sample location [a]	Number of samples	Uranium alpha [b] (pCi/m³)		
		Maximum	Minimum [c]	Mean [d]
July–December 1966:				
At plant perimeter fence:				
North	26	0.10	<0.02	<0.02
East	26	.17	< .02	< .02
South	26	.14	< .02	< .02
West	26	.06	< .02	< .02
Total, July–December 1966	104	0.17	<0.02	<0.02
Total, 1966	208	0.17	<0.02	<0.02
July–December 1966:				
About 1 mile outside plant perimeter fence:				
North	26	0.06	<0.02	0.02
East	26	.12	< .02	.02
South	26	.20	< .02	<0.02
West	26	.10	< .02	.02
Southeast	26	.13	< .02	.02
Total, July–December 1966	130	0.20	<0.02	0.02
Total, 1966	259	0.20	<0.02	<0.02

[a] See map in figure 1.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 alpha particle disintegrations/second.
[c] The minimum detectable concentration of uranium in air is 0.02 pCi/m³.
[d] The AEC radiation protection standard for natural uranium in air released to the environs beyond a controlled area is 2 pCi/m³.

samples collected during all of 1966 were both less than 1 percent of the AEC radiation protection standard set for individuals residing in the vicinity of a controlled area. The mean beta particle count of the same samples was 0.02 percent of the concentration limit.

The average uranium analysis of weekly water samples collected continuously from the Big Bayou Creek during July–December 1966 and during all of 1966 were both 0.05 percent of the radiation protection standards for water beyond a controlled area. The results of the uranium analyses for each of the 12 grab samples collected at monthly intervals from the Ohio River below the plant was less than 0.1 percent of the radiation protection standard.

Table 2. Beta radioactivity in outdoor air samples Paducah, July–December and calendar year 1966

Sample location [a]	Number of samples	Beta radioactivity (pCi/m³)		
		Maximum	Minimum[b]	Mean [c]
July–December 1966:				
At plant perimeter fence:				
North	26	0.93	<0.1	0.20
East	26	.74	< .1	.18
South	26	.95	< .1	.18
West	26	.95	< .1	.16
Total, July–December 1966	104	0.95	<0.1	0.18
Total, 1966	208	1.2	<0.1	0.21
July–December 1966:				
About 1 mile outside plant perimeter fence:				
North	26	0.79	<0.1	0.18
East	26	.89	< .1	.20
South	26	1.4	< .1	.23
West	26	.86	< .1	.18
Southeast	26	.90	< .1	.21
Total, July–December 1966	130	1.4	<0.1	0.20
Total, 1966	259	1.9	<0.1	0.19

[a] See map in figure 1.
[b] The minimum detectable amount of beta-particle emitters in air is 0.1 pCi/m³
[c] The AEC radiation protection standard, applicable to this table is 1×10^3 pCi/m³, which is the concentration limit of thorium-234, the daughter product of uranium-238. Insignificant amounts of other daughters are present in freshly refined uranium.

The concentration of beta-particle emitters in the Big Bayou Creek averaged 0.5 percent of the radiation protection standard for the decay products of uranium–238 during July–December 1966; the average for the year was 0.5 percent of the standard. The beta radioactivity of the Ohio River was at or below the minimum detectable level during July–December 1966, and the results of all samples during the year averaged 0.5 percent of the standard for uranium–238 decay products.

External gamma radiation in the vicinity of the Paducah Plant averaged 0.02 mR/hour at all sampling stations for July–December 1966 and calendar year 1966.

Table 3. Concentrations of uranium in water Paducah, July–December and calendar year 1966

Sample location [a]	Number of samples	Uranium [b] (pCi/liter)		
		Maximum	Minimum[c]	Mean [d]
July–December 1966:				
Big Bayou Creek 3	26	70	<1	10
Ohio River 6	6	1	<1	< 1
Composite of 50, 51, 52, and 53	6	1	<1	< 1
Year 1966:				
Big Bayou Creek 3	52	70	<1	10
Ohio River 9	12	1	<1	< 1
Composite of 50, 51, 52, and 53	12	1	<1	< 1

[a] See map in figure 1.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 alpha particle disintegrations/second.
[c] The minimum detectable uranium in water is 1 pCi/liter.
[d] The AEC radiation protection standard for natural uranium in water beyond a controlled area is 2×10^4 pCi/liter.

Table 4. Concentration of beta-particle emitters in water Paducah, July–December and calendar year 1966

Sample location [a]	Number of samples	Beta particle emitters (pCi/liter)		
		Maximum	Minimum[b]	Mean [c]
July–December 1966:				
Big Bayou Creek 3	26	100	<100	<100
Ohio River 9	6	400	<100	300
Composite of 50, 51, 52, and 53	6	100	<100	<100
Year 1966:				
Big Bayou Creek 3	52	600	<100	100
Ohio River 9	12	200	<100	100
Composite of 50, 51, 52, and 53	12	500	<100	100

[a] See map in figure 1.
[b] The minimum detectable amount of beta particle emitters in water is 100 pCi/liter.
[c] The AEC radiation protection standard for the immediate daughter products of uranium in water released to the environs is 2×10^4 pCi/liter.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December and Calendar year 1965	July 1966
January–June 1966	January 1967

2. Pinellas Peninsula Plant July–December 1966 [3]

General Electric Company
St. Petersburg, Florida

Pinellas Peninsula Plant, shown in figure 2, is an electronic component production facility. The plant maintains an environmental monitoring program to measure the levels of radioactive environmental contamination associated with plant effluents. These measurements serve as an index of the effectiveness of the plant's contamination control measures. Effluent radioactivity concentrations and associated atmospheric and stream dilution factors indicate offsite radioactivity concentrations encountered by the general population are substantially lower than the guides for continuous nonoccupational exposure established by AEC and documented in the "AEC Manual."

Sewer effluent monitoring

A combined sewer effluent sample is obtained daily near the perimeter of the plant's property. During the sampling period, 11 of 133 samples analyzed showed detectable concentrations of tritium (90×10^4 pCi/liter).[4] The maximum concentration (4.1×10^6 pCi/liter) which was detected on August 22, 1966, amounted to 137 percent of the continuous nonoccupational exposure guide. Calculations based on radioactivity releases from the process waste system, and the plant's water discharges, indicate that the average tritium concentration in the combined sewer effluent for July–December 1966 was less than 7.0 percent of the AEC radiation protection standard for continuous nonoccupational exposure.

Air monitoring

Air samples are obtained periodically in areas up to 2 miles downwind from the exhaust stack. Analysis of the two samples collected during the sampling period revealed no detectable

[3] Summarized from "Environmental Monitoring, July 1 through December 31, 1966" General Electric Company, Pinellas Peninsula Plant, St. Petersburg, Fla.

[4] Expressions in parenthesis indicate limits of detectability in the respective environmental samples.

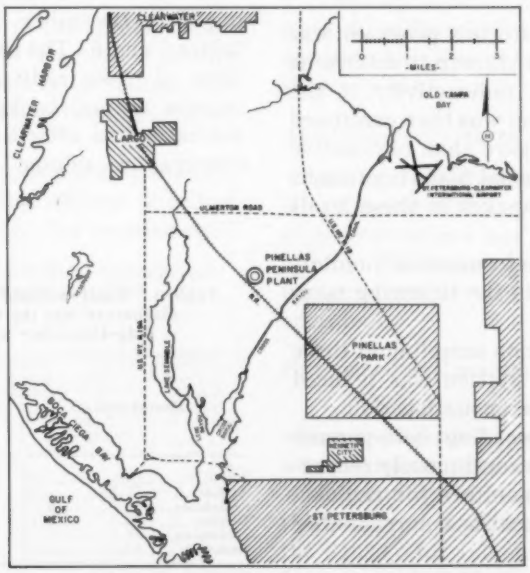

Figure 2. Location of the Pinellas Penisula Plant

amounts of tritium gas (9.6×10^6 pCi/m^3) or tritium oxide (5.0×10^3 pCi/m^3).

Surface water sampling

Surface water samples are collected at monthly intervals at selected locations within 8 miles of the plant. The sampling areas are determined by interrelating the concentrations of radioactivity in exhaust stack effluent with meteorological data. There were no indications of tritium oxide (9.0×10^4 pCi/liter) in the 45 surface water samples analyzed during the sampling period.

Milk sampling results

Eighteen samples of raw milk were collected from local dairy farms and analyzed by the Florida State Board of Health during July–December 1966. No detectable concentrations (9.0×10^4 pCi/liter) of tritium were evident.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	August 1966
January–June 1966	February 1967

3. Shippingport Atomic Power Station July–December and Calendar Year 1966 [5]

Duquesne Light Company
Shippingport, Pennsylvania

The Shippingport Atomic Power Station is operated for the Atomic Energy Commission by the Duquesne Light Company. The plant site is located near Shippingport, Pennsylvania, along the Ohio River about 25 miles northwest of Pittsburgh (figure 3).

An environmental monitoring program was begun 2 years before plant startup to determine the background levels of radioactivity in the environment. This program was then continued after plant startup to ensure that radioactive waste discharges from normal plant operations do not cause significant changes in these levels in the plant environment.

In January 1966, the environmental monitoring program was revised in the following manner:

1. Fallout and precipitation sampling at three locations surrounding the station was reduced to one sample taken at one onsite location.

2. The continuously recording beta-gamma radiation monitors and the continuously recording airborne particulate monitors for radioactivity situated at three locations surrounding the station were eliminated. For monitoring significant airborne releases of radioactivity in case of an accident, 12 film badges were located surrounding the station and changed on a quarterly frequency.

3. The sampling of river sediment upstream and downstream of the station's outfall was commenced on a quarterly basis.

Liquid radioactive waste disposal

The liquid radioactive wastes discharged during July–December 1966 are summarized in tables 5 and 6. The monthly average concentrations of gross radioactivity shown in table 5 include normal background radioactivity and are calculated after total radioactive waste discharges are diluted in the condenser-cooling

Table 5. Total radioactive waste, exclusive of tritium, discharged into the Ohio River, Shippingport July–December and calendar year 1966

Period 1966	Total discharge (mCi)	Average discharge (mCi/day)	Average concentration in effluent channel (pCi/liter)
July	2.05	0.066	1.34
August	3.96	.128	1.80
September	2.90	.097	0.57
October	10.18	.328	3.94
November	6.63	.221	3.94
December	3.35	.108	2.94
Total discharge and grand average, July–December	29.07	0.158	2.04
Calendar year 1966	56.3	0.15	2.38

[5] Summarized from "Environmental Radioactivity at the Shippingport Atomic Power Station for the Second Half of 1966 and Calendar Year 1966" PNR–SMD–141.

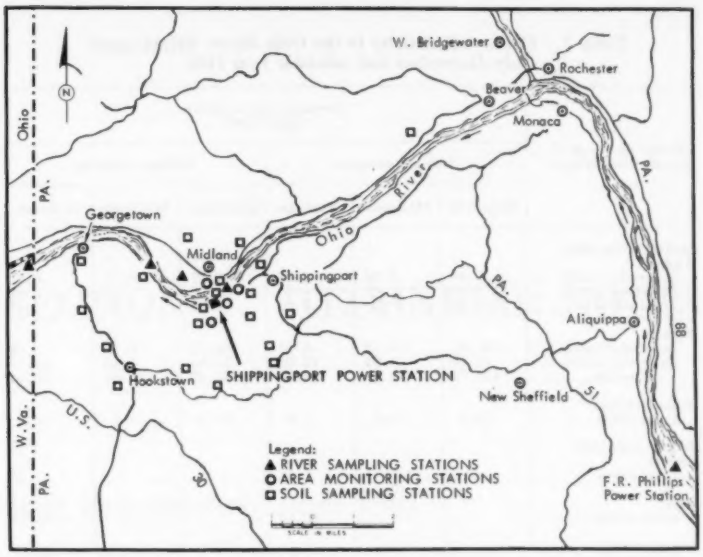

Figure 3. Shippingport power station sampling locations

water effluent channel. The maximum total discharge in 1 day during July–December 1966 was 1.33 millicuries.

Table 6 is a summary of the tritium that was discharged into the Ohio River, the monthly average concentration of tritium in the holdup tanks prior to discharge, and monthly average concentration of the waste in the effluent channel after dilution with the condenser-cooling water. The maximum quantity of tritium discharge in 1 day during July–December 1966 was 586 millicuries.

Automatic samplers are installed at the station's river water influent and effluent to collect water samples continuously for comparative purposes. The continuous samples were analyzed for gross beta and gross alpha radioactivities in the suspended and dissolved solids. The potassium–40 radioactivity in the total solids of these samples was also measured. No significant difference was observed between the average alpha-particle, beta-particle and potassium–40 radioactivity in the influent and effluent samples. The results of these analyses are shown in table 7.

Table 6. Tritium released to Ohio River, Shippingport July–December and calendar year 1966

Period 1966	Total discharge (mCi) (multiply by 10^3)	Average discharge (mCi/day)	Average concentrations in hold-up tanks (nCi/liter) (multiply by 10^4)	Average concentrations in effluent channel (nCi/liter)
July	2.01	64.9	1.86	2.98
August	3.02	97.5	2.17	2.36
September	2.11	70.4	1.58	1.05
October	5.30	171.0	1.28	3.66
November	3.41	114.0	1.49	3.92
December	2.54	81.9	1.34	3.87
Total discharge and grand average, July–December	18.4	100.0	1.52	2.66
Calendar year 1966	27.3	74.9	----------	2.10

Atmospheric releases of radioactive materials

During July–December 1966, a total of 293 μCi of xenon–133 was released at Shippingport at concentrations less than the MPC of 3×10^5 pCi/m^3. The incinerator, which is used for burning combustible contaminated waste was not operated.

Environmental monitoring

Twelve beta-gamma sensitive film badges which were posted around the station boundary to determine external radiation levels again showed faulty results. The density readings for the background control films were greater than the density for the environmental films during July–December 1966. Three modifications have been incorporated in the Shippingport procedures in an effort to solve the present problems.

Table 7. Gross radioactivity in the Ohio River, Shippingport July–December and calendar year 1966

Period and type of radioactive material	Average concentration (pCi/liter)					
	Influent samples			Effluent samples		
	Maximum	Minimum	Average	Maximum	Minimum	Average
July–December 1966:						
Alpha:						
Suspended solids	0.40	0.04	0.18	0.51	0.03	0.20
Dissolved solids	2.33	.17	.84	2.00	.11	.92
Total solids	2.45	.24	1.02	2.35	.24	1.11
Beta:						
Suspended solids	81.83	0.22	6.61	34.75	0.32	5.79
Dissolved solids	70.89	1.94	12.05	33.86	1.46	13.75
Total solids	152.72	4.69	18.66	59.16	3.54	19.54
Potassium-40:						
Total solids	10.5	3.5	7.9	10.0	3.6	7.6
Calendar year 1966:						
Alpha:						
Total solids	----------	----------	1.63	----------	----------	1.04
Beta:						
Total solids	----------	----------	16.43	----------	----------	15.74
Potassium-40:						
Total solids	----------	----------	6.3	----------	----------	6.1

(1) A change was made in the film-badge packaging technique. (2) One-month exposures will be tried at some of the perimeter stations to indicate if the length of the exposure period affects the exposure rate. The present exposure period is one calendar quarter. (3) The control film will be packaged and mounted at some unaffected location offsite to help compensate for natural environmental conditions as a film effect. Past control films have been stored in the darkroom throughout the exposure period.

River sediment samples were collected from the Ohio River once each calendar quarter upstream and downstream from the station's liquid waste outfall. These samples were analyzed for gamma-ray activity, and quantitated assuming all detected radioactivity to be cobalt–60, which is the major constituent of radioactive contamination at the station. Concentrations of radioactivity in the sediment for the third and fourth calendar quarters were, respectively, 9.24 and 8.79 pCi/g upstream and 9.68 and 9.55 pCi/g downstream from the outfall. These results indicate that there was no appreciable increase of radioactivity in the river sediment as the result of the station's discharges of radioactive contaminated liquid wastes.

Radioactive fallout was collected in a pot at one onsite location and analyzed weekly for alpha and beta radioactivity. The average quarterly and semiannual results are depicted in table 8.

Table 8. Radioactivity in fallout, Shippingport July–December and calendar year 1966

Period	Deposition rate (nCi/m^2/month)	
	Alpha radioactivity	Beta radioactivity
Third quarter 1966	0.13	4.08
Fourth quarter 1966	.34	7.18
July–December, 1966	.24	5.63
Calendar year 1966	.32	13.32

Summary

During July–December 1966 and for the calendar year 1966, measurements of radioactivity were made in the Ohio River and in the vicinity of the Shippingport Atomic Power Station. The results of these measurements indicate that the radioactive material released by the power station into the Ohio River did not result in a significant change in the naturally occurring radioactivity in the environment.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	July 1966
January–June 1966	February 1967

SECTION V. TECHNICAL NOTES

Reported Nuclear Detonations, June 1967

The Atomic Energy Commission announced on June 17 that the Chinese detonated a nuclear device at their Lop Nor site. The yield was in the range of several megatons. This is the sixth Chinese nuclear test confirmed by the United States.

Three underground nuclear tests of low yield (less than 20 kilotons TNT equivalent) were conducted by the U.S. Atomic Energy Commission at its Nevada Test Site on June 22, 26 and 29, respectively. The test of June 22 was part of the Plowshare program which is part of an effort to develop nuclear devices experimentally designed for peaceful purposes. This test is one of a series to develop devices for use in possible later excavation experiments.

There was a small release of radioactivity from the June 29 test. While most of this radioactivity was deposited within the Test Site, very low levels of radioactivity have been detected on the ground near the Site. The highest of these was 0.7 milliroentgen per hour in an unpopulated area about three miles from the boundary of the Government-controlled reservation. This reading dropped to near background levels within an hour. This level of radioactivity presents no health hazard.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

DISTRIBUTION OF STRONTIUM AND CALCIUM IN MAJOR VEGETABLE AND FRUIT CROPS AND CRITERIA FOR USE OF FALLOUT-CONTAMINATED FOODS. *J. W. Ralls, S. Primbsch, T. R. Guckeen, H. J. Maagdenberg, J. Rinehart, F. C. Lamb, and W. A. Mercer. Radiological Health Data and Reports, Vol. 8, July 1967, pp. 355–358.*

Vegetable and fruit crops were grown in soil enriched with high levels of strontium nitrate. The normally edible portions of the crops were harvested and sectioned into anatomically distinct portions. The strontium and calcium content was measured by flame spectrophotometry or by photon activation analysis. The results are tabulated to provide an upper limit for radiostrontium content of crops grown in soil heavily contaminated with debris from nuclear fission on a massive scale.

KEY WORDS: calcium, crops, decontamination, fruits, strontium–90, strontium to calcium ratio, vegetables

AERIAL MEASUREMENT OF THE KIWI TRANSIENT NUCLEAR TEST. *R. D. Coleman and V. E. Andrews. Radiological Health Data and Reports, Vol. 8, July 1967, pp. 359–366.*

The Los Alamos Scientific Laboratory conducted a Transient Nuclear Test on a KIWI Reactor on January 12, 1965, at the Nuclear Rocket Development Station at Jackass Flats, Nev. During this planned destructive test of a propulsion reactor, the Public Health Service's Southwestern Radiological Health Laboratory conducted a land and aerial offsite radiological surveillance program. The aerial aspects of the Laboratory's program include sampling and assay missions along flight patterns through the radioactive cloud formed by the destruction of the reactor. Samples obtained from these aerial missions were analyzed to define various characteristics of the cloud. The decrease of peak gamma-ray readings with distance from the site of the experiment was exceptionally rapid. The reduction is attributed to a combination of decay and excellent meteorological diffusion.

KEY WORDS: aerial, cloud, KIWI Transient Nuclear Test, nuclear reactor, radioactive release, radionuclides

SUMMARY OF POPULATION EXPOSURE TO X-RAYS IN THE UNITED STATES, 1964. *Population Studies Program, National Center for Radiological Health, Radiological Health Data and Reports, Vol. 8, July 1967, pp. 367–373.*

A summary of the highlights of *Population Exposure to X-rays, U.S., 1964, A Report on the Public Health Service X-Ray Exposure Study*, PHS Publication No. 1519 is presented. It is estimated that 58 percent of the 187 million civilian noninstitutional population of the United States had one or more X-ray visits. The estimated annual dental X-ray rate declined from 27.4 per 100 persons in 1961 to 26.8 in 1964. The estimated annual rate of medical X-ray visits increased from 47.9 per 100 persons in 1961 to 49.8 in 1964. Of the 173 million X-ray examinations or procedures performed during these visits, 105 million were radiographic, 54 million dental, 10.5 million fluoroscopic, and 3.5 million X-ray therapy. The estimated number of X-ray films taken were 506 million.

KEY WORDS: dental X-rays, fluoroscopy, medical X-rays, population exposure, X-rays

GUIDE FOR AUTHORS

The editorial staff invites reports and technical notes containing information related to radiological health. Proposed reports and notes should contain data and interpretations. All accepted manuscripts are subject to copy editing with approval of the author. The author is responsible for all statements made in his work.

Manuscripts are received with the understanding that other identical manuscripts are not under simultaneous consideration nor have appeared in any other publication.

The mission of *Radiological Health Data and Reports* is stated on the title page. It is suggested that authors read it for orientation of subject matter.

Submission of manuscripts

Send original and one legible copy of the paper, typed double-spaced on 8½ by 11-inch white bond with 1-inch margins.

Submitted manuscripts should be sent to Managing Editor, Radiological Health Data and Reports, National Center for Radiological Health, PHS, Rockville, Md. 20852.

Preparation of manuscripts

The Government Printing Office style manual is used as a general guide in the preparation of all copy for *Radiological Health and Reports*. In addition, *Radiological Health Data and Reports* has developed a "Guide" regarding manuscript preparation which is available upon request. However, for most instances, past issues of *Radiological Health Data and Reports* would serve as a suitable guide in preparing manuscripts.

Titles, authors: Titles should be concise and informative enough to facilitate indexing. Names of authors should appear on the third line below the manuscript title. Affiliation of each author should be given by a brief footnote including titles, professional connections at the time of writing, present affiliation if different, and present address.

Abstracts: Manuscripts should include a 100- to 150-word abstract which is a factual (not descriptive) summary of the work. It should clearly and concisely state the purpose of the investigation, methods, results, and conclusions. Findings that can be stated clearly and simply should be given rather than to state that results were obtained.

A list of suggested keywords (descriptors) which are appropriate indexing terms should be given following the abstract.

Introductory paragraph: The purpose of the investigation should be stated as early as possible in the introductory paragraph.

Methods: For analytical, statistical, and theoretical methods that have appeared in published literature, a general description with references to sources is sufficient. New methods should be described clearly and concisely with emphasis on new features. Both old and new methods, materials, and equipment, should be described clearly enough so that limitations of measurements and calculations will be clear to the readers. Errors associated with analytical measurements and related calculations should be given either as general estimates in the text or for specific data in appropriate tables or graphs, whenever possible.

Illustrations: Glossy photographic prints or original illustrations suitable for reproduction which help enhance the understanding of the text should be included with the manuscript. Graphic materials should be of sufficient size so that lettering will be legible after reduction to printed page size (8½ by 6½ inches).

All illustrations should be numbered and each legend should be typed double-spaced on a separate sheet of paper. Legends should be brief and understandable without reference to text. The following information should be typed on a gummed label of adhesive strip and affixed to the back of each illustration: figure number, legend, and title of manuscript or name of senior author.

Tables: Tables should be self-explanatory and should supplement, not duplicate, the text. Each table should be typed on a separate sheet, double-spaced. All tables must be numbered consecutively, beginning with 1, and each must have a title.

Equations: All equations must be typewritten, preferably containing symbols which are defined immediately below the equation. The definition of symbols should include the units of each term. Special symbols, such as Greek letters, may be printed carefully in the proper size, and exponents and subscripts should be clearly positioned. Mathematical notations should be simple, avoiding when feasible, such complexities as fractions with fractions, subscripts with subscripts, etc.

Symbols and units: The use of internationally accepted units of measurements are preferred. A brief list of symbols and units commonly used in *Radiological Health Data and Reports* is given on the inside front cover of every issue and examples of most other matters of preferred usage may be found by examining recent issues. Isotope mass numbers are placed at the upper left of elements in long series or formulas, *e.g.*, ^{137}Cs; however, elements are spelled out in text and tables, with isotopes of the elements having a hyphen between element name and mass number; *e.g.*, strontium–90.

References: References should be typed on a separate sheet of paper.

Personal communications and unpublished data should not be included in the list of references. The following minimum data for each reference should be typed double-spaced: names of all authors in caps, complete title of article cited, name of journal abbreviated according to *Index Medicus*, volume number, first and last page numbers, month or week of issue, and year of publication. They should be arranged according to the order in which they are cited in the text, and not alphabetically. All references must be numbered consecutively.

Reprints

Contributors are ordinarily provided with 50 courtesy copies of the articles in the form of reprints. In cases of multiple authorship, additional copies will be provided for coauthors upon request.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1967—231-410

ORDER BLANK FOR RHD&R

To: Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

Please enter my subscription for Radiological Health Data and Reports. I am enclosing Money Order ☐ Check ☐ for this subscription. ($5.00 a year; $1.50 additional for foreign mailing.)

Please address RHD&R as follows. _____

_____

_____

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C., 1965

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Subscription price $5.00 a year, $1.50 additional for foreign mailing.
Price for a single copy of this issue is 50 cents.

July 1967

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
WASHINGTON D.C. 20201

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF H.E.W.

If you do not desire to continue receiving this publication, please CHECK HERE ☐; tear off this label and return it to the above address. Your name will then be promptly removed from the appropriate mailing list.

TER
STAG
ERN
S
OFFIC
MENTS
2940
IESS

UNIVERSITY MICROFILMS SERIALS SECTION
300 NORTH ZEEB RD
ANN ARBOR MICH